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THESIS

entitled

"STUDIES ON THE NUTRITIVE VALUE OF FRESH AND CONSERVED GRASS WITH SPECIAL REFERENCE TO SILAGE"

submitted

by

PETER McDONALD B.Sc.(Hons.)(Dunelm), M.Sc.(Dunelm), A.R.I.C.

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CONTENTS

INTRODUCTION

The conservation of forage crops for winter feeding is of fundamental importance in the economy of British farming. The most widely used method of conserving herbage is drying by natural means and that this is a wasteful process has been stressed by many workers. Watson (1939) has stated that even under normal conditions, 'good' hay loses some two-fifths of the starch equivalent of the original crop and one-third of the digestible protein during making. The mere fact that haymaking is at the mercy of the weather introduces a factor which renders impossible any reliable assessment, based on the original crop, of the nutritive value of the final product. In addition to the changes which may occur during the drying process the transportation of the dried product to the stack does not necessarily terminate the chemical changes and losses of constituents which can occur in the stored material. Although the losses due to fermentation in the stack may be relatively low when the material has been stored in a thoroughly dry condition (Watson 1939; Poijarvi 1950;), in many cases considerable losses and reduction in digestibility due to overheating can occur (Wiegner 1934; Gaardman 1935; Isaachsen et al. 1932;). Fagan and Ashton (1937) have reported in one haymaking experiment dry matter losses of 10 per cent in the field and 16 per cent in the stack; whilst this latter figure might be exceptional, it does demonstrate that haymaking is far from being a satisfactory system of fodder conservation. Furthermore there is a general tendency to overestimate the feeding value of hay. Smith and Comrie (1948) have examined 64 samples of seeds hay obtained from the Lothians and found that the average crude protein value was only/

only 6.08 per cent. The fact that hay produced in this area is of low nutritive value is, in some measure, due to the tendency of farmers to delay cutting the crop until the grasses are too mature, although the frequent unfavourable nature of the climatic conditions during the drying process is also an important factor in reducing the nutritive value.

The many difficulties which are encountered in haymaking can be eliminated or reduced by artificial drying of the green fodder. This process is one of the most efficient methods of conservation, since the fermentative changes in the green crop are arrested immediately. Provided overheating during the drying process does not occur, then this system can produce a food of similar nutritive value to that of the fresh material since the digestibility and composition of the crop are not affected under normal conditions by artificial drying (Watson 1938). Although this method is undoubtedly one of the best its practice is necessarily limited because of the high cost involved (Heath 1948).

The third method of conserving fresh herbage is by ensilage. This method involves the exclusion of air by proper compaction and the rapid production of a desirable degree of acidity in the mass, either by direct addition of weak acid solutions, the addition of preservatives such as sodium metabisulphite, or the stimulation of lactic-acid formation by micro-organisms present on the fresh herbage. The process of ensilage has the advantage over haymaking in that it is largely independant of the weather although Smith (1954) has shown a relationship between the amount of/

of summer rainfall and the dry matter, crude protein and pH values of silages.

A considerable number of experiments have been carried out in order to compare the losses involved in silage making with those encountered during haymaking. Brouwer (1930) and Craseman (1924) have reported that under Dutch conditions, in good hay weather, the silage process could afford little advantage over haymaking. In the U.S.A. Woodward (1939) has stated that silage and best field-cured hay are about equal in nutritive value. Hodgson et al. (1946) have compared silage making, barn curing and field curing and have concluded that ensilage preserved slightly more dry matter and protein per acre. Whilst the losses encountered during haymaking on the Continent and in the States can be relatively low, the losses which occur under farming conditions in the U.K., compared with ensilage, are generally of a greater magnitude.

The figures quoted in the literature for losses during ensilage vary considerably. Watson (1939) in one experiment using 5 wooden silos of two tons capacity ensiled similar grass in each and the losses in dry matter recorded ranged from 13.7 - 30.5 per cent. The lower figure compared with figures obtained for a large silo filled with grass from the same field at the same time. It is generally agreed that, in conditions encountered in South East Scotland, the losses in silage making where the process is satisfactorily carried out are much lower than those encountered during haymaking.

In/

In spite of the many advantages of silage making over haymaking as a conservation process, it is not a popular system of conserving herbage in Scotland. Whilst it is true that the quantities of silage made have increased in recent years,(Watson and Nash 1954) the acreage of grassland devoted to the ensilage process is relatively small compared with that used to produce hay as can be seen in the following Table (Agric. Statistics 1951-53).

TABLE 1

Hay and silage acreages for Scotland 1951-53

	1951	1952	1953
Hay			
From temp. grassland	383,072	387,664	363,597
From perm. grassland	116,123	106,371	96,914
From timothy meadow	37,318	36,136	33,509
Total	536,513	530,171	494,020
Silage	36,888	44,340	49,978

Several reasons can be put forward for the unpopularity of silage making and one important reason is the variations which can occur in the quality and feeding value of the final product. The nutritive value of silage can vary considerably depending upon the nature of the crop, stage of growth, and changes in the mass during the ensilage process.

The purpose of this investigation has been to study the effects of pH and/

and the wilting of grass prior to ensiling, on the nutritive value of silages. In addition the effects of soluble sugar reduction during the ensilage process on the utilisation of fibre and nitrogenous compounds by livestock and the assessment of digestibility and dry matter intake of silage, based on chemical composition, have been studied. The implications of these different factors are discussed below.

pH and nutritive value of silages.

The assessment of success in silage making is often decided by the pH value of the finished product, but experimental evidence for the relationship between degree of preservation and food value is still lacking. Watson (1939) has stated that it is difficult to assign any definite value to 'bad' silage, because in some cases, where it is classed as 'bad' largely by virtue of its butyric acid content, it may still have a high Starch Equivalent (S.E.) value. A pH value of 4.5 is normally accepted as a convenient point to distinguish between 'good' and 'bad' silages, although this does not necessarily apply either to the nutritive value or the palatability, since animals often relish silages which by human standards would be classed as very bad silages.

It is generally agreed that excessive protein breakdown during ensilage is undesirable although the degree of breakdown is not of such importance as the nature of the breakdown products. High pH silage may be dangerous to stock because of the possibility of such silage containing toxic substances./

substances. However despite general agreement that it is desirable to produce silage of pH value less than 4.5, in practice a considerable quantity of 'bad' silage is produced and it is of some importance to investigate the nutritive value of such silage.

Effect of wilting on the nutritive value of silages.

It is important in successful silage making to minimise the degree of waste due to fermentation and effluent loss. It is possible to produce silage of high nutritive value even if large losses of nutrients occur during the period of preservation, but this is not only wasteful but uneconomic. Fermentation losses are largely dependent on three factors, viz. the degree of consolidation, the chemical composition of the original green crop (except where soluble sugars have been added), and the activity of bacteria. The amount of loss due to effluent waste is largely related to the original moisture content of the crop at the time of ensiling: that this loss can be appreciable has been stressed by Murdoch (1954). Dijkstra (1951) has also compared the effluent losses in two molassed grass silages in which the drainage tap of one silo was kept open while the other silo tap was closed. There was little difference in quality between the resulting silages although losses from the drained silo were considerably greater than from the closed silo.

This system of making silage in sealed containers is one way of preventing effluent loss, although in the majority of cases quite impracticable/

impracticable under farming conditions. An easier and better method of reducing effluent loss is by partial wilting of the fresh crop in the field, prior to ensiling (Archibald and Gunness 1945). Scharrer, Schreiber and Kuhn (1952) have investigated the effects of wilting upon the composition of alfalfa and found that this process had no marked effect except to raise pH and increase the percentage of total volatile acids. On the other hand Macpherson (1952) has stated that protein breakdown in wilting grass can be very rapid and as much as 16 per cent of protein can be degraded to simpler substances in 24 hours. More recently Nash (1956) has studied this process under farming conditions in S.E. Scotland in great detail and has concluded that partial wilting of long herbage can be carried out satisfactorily even in poor weather conditions, although the probability of overheating occurring in trench silos is increased unless precautions are taken during the filling process. The bruising of herbage in addition to wilting is a distinct advantage in permitting more efficient consolidation in the silo.

Utilization of nitrogenous compounds in silage by livestock.

Reference has been made to the effects of the ensilage process upon protein breakdown and although it is generally regarded as being undesirable there is very little information available as to the extent of utilisation of nitrogenous products in silage by the ruminant animal.

In the case of single stomached animals the Biological Values of food proteins are generally related to their amino acid composition (Maynard 1947). Unfortunately/

Unfortunately in the case of ruminant animals, this does not necessarily apply. Ruminants, with the exception of the period when they are suckling, (Blaxter and Wood 1950) have an alimentary microflora which is encouraged by the dynamics of the digestive system to attack the feed for a considerable time, and these micro-organisms have wide powers of synthesis. When urea is given as the sole source of nitrogen all ten of the essential amino acids are found in the rumen in approximately the same quantities as after feeding a good quality protein (Thomas et al. 1949). It is not surprising, therefore, that for ruminants proteins in the common feeding stuffs, whether animal or vegetable, are generally similar in Biological Value (McNaught and Smith 1947).

In view of the many microbiological reactions which can occur in the rumen it is reasonable to assume that utilization of nitrogenous compounds in foods will vary considerably. Pearson and Smith (1943) showed that ammonia increased when urea and maltose were added to rumen liquor in vitro, and that a subsequent increase in protein due to bacterial growth ensued, and postulated that ammonia was the source of nitrogen. MacDonald (1948) was the first to relate the concentration of ammonia in rumen liquor of sheep to feeding, and to the nature of individual proteins introduced into the rumen; he established that ammonia was also absorbed from the rumen, a finding that suggested that bacterial disintegration of protein was not necessarily economical for the animal. Investigations into the formation of ammonia from proteins in the rumen have been carried out by Chalmers, Cuthbertson and Synge (1954) and Chalmers and Synge (1954). These workers

have/

have shown that extensive conversion of casein to ammonia can occur in the rumen with absorption of ammonia into the blood stream.

Annison et al. (1954) have stated that it is to be expected that the presence of readily fermentable carbohydrate in the rumen will encourage dominance of those types of micro-organisms which obtain their energy therefrom. Amino acids arising by proteolysis will be assimilated by the growing micro-organisms under these conditions, whereas in the absence of fermentable carbohydrate amino acids will accumulate and undergo fermentation of the Stickland type, yielding products of little value for satisfying the nitrogen requirements of the animal. Thus addition of easily fermentable carbohydrate to a ruminant diet may have this direct effect of conserving protein in the intestinal tract independent of any parallel effect which the ratio of protein to carbohydrate intake may have on the nitrogen balance of the animal as a whole.

Thus in view of the importance of carbohydrates in nitrogen utilization by the animal it is necessary to ascertain what effects this has on the utilization of silage. During ensilage, a considerable loss of soluble sugars occurs in the silo by fermentation to lactic acid, and to a lesser extent, to volatile fatty acids in the range C_1 to C_8 (Barnett and Duncan 1954) and it is possible that this reduction in carbohydrates is likely to have some effect upon utilization of nitrogenous compounds in silage by the ruminant animal.

That breakdown of proteins during ensilage can be considerable has been shown by a number of workers. Gneist (1937) in his investigations showed that/

that in fresh grass the free α -amino-nitrogen was 20 per cent of the non-protein nitrogen, whereas in silage it was 40 per cent and ammonia-nitrogen had increased from 2 per cent to about 12 per cent. These figures were for a 'good' silage; the protein loss in a 'bad' silage could be much higher with a further breakdown of amides to ammonia. McPherson (1952) has stated that except perhaps in cases of marked carbohydrate shortage, protein breakdown is almost entirely due to enzyme action, at least until the collapse of the cells, when putrefactive bacteria may take over and carry breakdown further provided the acidity is not too great.

There is evidence from the work of Kirsch and Jantzon (1933) and Edin, Berglund and Andersson (1933) that non-protein nitrogenous compounds produced from proteins during silage making are a good source of nitrogen for ruminants. Watson (1936) has stated that the disadvantage of protein breakdown in silage has been over-emphasised in the past; the breakdown products are of high nutritive value for dairy cows, though this does not refer to bad samples of silage in which the breakdown proceeds to the stage of excessive volatile base formation. In an experiment carried out by Watson and Ferguson (1936), artificially dried grass, molassed silage or A.I.V. fodder supplied approximately half the total digestible crude protein in three experimental rations in the diets of dairy cows. In spite of the fact that the non protein nitrogenous compounds of the molassed silage supplied 32 per cent of the total digestible crude protein intake, there was no significant difference between treatments in yield of milk, butter fat, butter fat percentages or liveweight of the cows.

Morris,/

Morris, Wright and Fowler (1936) have studied the nutritive value of proteins in three types of silages made from summer grass and showed that the Biological Value of each was equivalent to that of fresh spring grass. The reduction in soluble carbohydrates during ensilage upon utilisation of nitrogenous compounds has been considered in these studies.

Utilization of fibre in silage by livestock.

A necessary condition of the symbiosis responsible for cellulose breakdown, as it occurs in a ruminant grazing under natural conditions, is the conversion into lower fatty acids (Elsden 1946) of a proportion of the soluble carbohydrates existing in situ in the fodder and derived from the crude fibre; any substantial reduction in soluble carbohydrate content of herbage, such as occurs during ensilage, might interfere with the ability of the ruminant micro-organisms to breakdown cellulose.

Hoflund, Quin and Clark (1948) have stated that optimal cellulose digestion necessitates the maintenance of a balance between readily available carbohydrate and protein. These workers showed that both rate of cellulose digestion and appetite were increased in sheep maintained on a diet of poor quality grass hay when small amounts of sugar were added. These and other results obtained (Clark and Quin 1951) indicate that the rate of cellulose digestion in the ruminant may be simply related to the proportion of fibre, soluble carbohydrate and nitrogen in the ration. It is possible that a deficiency in soluble carbohydrates, such as might result from ensilage of unmolassed grass of high-medium protein content, might affect/

affect the rate of cellulose digestion to an extent which could not be compensated by a different rate of turn-over from the rumen. This reduction of soluble carbohydrates during ensilage upon fibre digestibility has been considered in these studies.

Assessment of nutritive value.

The usual method of assessing the nutritive value of feeding stuffs is based on the determinations described in the Fertilisers and Feeding Stuffs Regulations (1932). This system of proximate analysis, which was first introduced by Henneberg in 1860, involves the determination of crude protein, ether extract, crude fibre, nitrogen-free-extractives and ash and is still used today in essentially the same form as first introduced (Browne 1940). This method of analysis has been frequently criticized as being inadequate since it provides no assessment of individual chemical components in foods. In spite of its limitations, however, no satisfactory alternative method has been developed which has been considered adequate to replace it. In view of the number of analyses that have been made by this method there is a general reluctance to introduce a new system (Hallsworth 1949). The chief criticisms have been levelled at the determinations of carbohydrate constituents by means of two fractions - crude fibre (C.F.) and nitrogen-free-extractives (N.F.E.). The measurement of these was an attempt to divide the food constituents into indigestible and digestible portions, but it was later discovered that the N.F.E. fraction contains/

contains portions of relatively indigestible materials, such as lignin, and the C.F. fraction is digested to a very considerable extent by ruminants (Browne 1940). Crampton (1939) has pointed out that in pasture herbage crude fibre may be just as digestible and often even more digestible than the N.F.E. Furthermore Armstrong, Cook and Thomas (1950) have shown that crude fibre does not represent a single plant constituent, and its composition varies to a substantial extent between species, and in any one species at different stages of growth. The term N.F.E. has been criticized for the reason that it does not represent a single constituent, but a residuum of numerous undetermined substances of variable nutritive value, the calculation of which by difference is vitiated because of errors involved in determining protein, fat, fibre and ash. Since the main object of this work was to investigate the nutritive value of silages, it was considered necessary to adhere to the routine methods of analysis since any serious deviation would make comparison with previous work and calculation of Starch Equivalent and Total Digestible Nutrient values impossible. However, because of the limitation of the C.F. and N.F.E. determinations, an alternative method of estimating the carbohydrate constituents has been investigated.

A number of different schemes of analysis has been suggested. Norman (1939) has stated that the determination of lignin would be of more value than the crude fibre estimation although substitution of lignin for crude fibre would substantially increase the size of the N.F.E. fraction. Hallsworth (1950) has suggested that a "crude fibre" determination based on an acid digestion only should give a much better correlation with digestibility of/

of the feeding-stuff, and a much closer relationship to its starch equivalent. Many workers now prefer, as suggested by Crampton and Maynard (1938) to determine lignin, cellulose and other carbohydrates (by difference) rather than C.F. and N.F.E. This is a distinct advance but a large fraction remains undetermined and a few workers have endeavoured to gain further information about the carbohydrate constituents, structural and non structural. Phillips and Smith (1940) have carried out a comprehensive analysis of herbage, and accounted for some 89% of the dry matter of timothy grass. A scheme for the analysis of herbage has been proposed by Ferguson (1948) who divided the constituents into a total of 12 groups. Percival (1952) has suggested a similar scheme for the division of carbohydrates into structural and non-structural units (Table 2).

TABLE 2

FERGUSON		PERCIVAL	
Non structural constituents	Structural Constituents	Non structural Constituents	Structural Constituents
Ash	Pectin	Monosaccharides	Cellulose
Crude protein	Cellulose	Oligosaccharides	Pentosans
Ethyl ether extract	Cellulosan	Fructosan	Galactan
Total sugars, less fructosan	Polyuronides		Pectin
Fructosan	Lignin		Glucosans
Organic acids, as malic			
Undetermined fraction			

The majority of the aforementioned suggestions for carbohydrate analysis involves a considerable number of lengthy individual estimations and for this/

this reason have not been adopted for routine purposes.

A considerable amount of attention has been devoted to the determination of lignin. Several methods have been proposed. (Ellis, Matrone and Maynard 1946) (Norman and Jenkins 1933) (Goss and Phillips 1936) (Waksman 1930) (Williams and Olmstead 1935). Hallsworth (1950) has studied several of these methods and has shown that small but appreciable differences do exist between the values obtained for any one feeding stuff. Thomas and Armstrong (1949) have reviewed the methods used for the determination of lignin involving the use of 72 per cent sulphuric acid and have produced evidence for the necessity of applying a nitrogen correction to the lignin as found. Moon and Abou-Raya (1952) have shown that the isolation of pure lignin is difficult because of possible contamination of lignin residues with carbohydrates reprecipitated on dilution of the 72 per cent sulphuric acid; these workers have also produced evidence that the methoxyl content is not constant but varies with the plant species and the degree of maturity. Norman (1937) has stated that there is evidence that the lignin of different species is not identical and he has suggested that lignin may be a complex mixture of compounds with similar properties but of unrelated chemical structure, or else a mixture of compounds similar in structure but which vary in minor ways. Many workers have found that dietary lignin is not appreciably metabolized by animals (Woodman and Stewart 1932; Crampton and Maynard 1938), although there is also evidence that lignin from certain species of plants can be digested to quite a marked degree (Lancaster 1943; Louw 1941). Armstrong and Thomas (1953 have reported

a/

a digestibility of lignin in heather of 10 per cent. The recovery in faeces of up to 23 per cent more lignin than has been fed in the herbage eaten (Forbes and Garrigus 1948) raises grave doubts as to the adequacy of the analytical methods at present in use. Richards and Reid (1952) have also found lignin recoveries greater than 100 per cent and this they consider as being due to interfering substances in the faeces. The problem is certainly complicated by the wide range of methods used for the analysis of lignin, and by the lack of definition of the component. Lancaster (1943) and Forbes and Garrigus (1950) found that faecal lignin contained a higher percentage of nitrogen than food lignin, producing discrepancies in the digestibility data. It seems obvious from these results that further work on the constitution of lignin is desirable before it can be adopted as a routine method in feeding stuffs analysis.

A method of analysis of different carbohydrate groups based on Percival's original classification (Table 2) has been devised by Harwood (1954). The method consists essentially of treating the food with a number of successive extractions and subsequent hydrolyses followed by determination of total reducing values of the resulting monosaccharides. The advantages of such a system enables the same sugar determination to be applied to each hydrolysed fraction. A modification of this system of analysis was adopted for carbohydrate estimations in these studies.

EXPERIMENTAL METHODS

(i) Metabolism Experiments

(a) Equipment:- In addition to the collection of faeces for calculation of digestibility coefficients, urine was also collected and analysed in order to determine the nitrogen balance. For complete separation of urine from faeces it was necessary to house the animals in individual crates. The first type of crate used for this purpose involved the collection of faeces by bag and harness, the bag being detached from the harness by means of six press studs evenly distributed around the ring of fabric attached to the rear straps (see Figs. 1 and 2).

In this type of crate the animals stand on a grid through which the urine passes and drains into a collecting vessel via a zinc funnel built into the floor of the crate. It can be seen from Fig. 2 that this type of crate is not completely enclosed and because of this a considerable amount of food can be thrown out onto the floor by the animals whilst feeding. Although periodic inspections can be made with this type of crate in order to return the food to the feeding box, this system can be improved upon. It was therefore decided to construct new crates to overcome this problem of food scattering and also to modify the systems of faecal and urine separation in order to reduce the labour of faeces collection.

Several designs of metabolism crates have been described by various workers. Those of Hodgson et al.(1935) and Briggs and Heller (1940) are modifications of the crate designed by Forbes (1915). Burkitt (1940) and Sotola (1927) have used similar crates which have a complete false floor of heavy wire screen upon which the animal stands. A removable screen of smaller/

Fig. I.

Fig. 2.

Fig. 3.

smaller mesh below the false floor catches the faeces and permits the urine to run through a funnel shaped pan which directs the flow of urine into a collection bottle beneath the crate.

A crate similar in principle to this design and similar to one which had been constructed previously for the determination of digestibility of Medicago sativa (McDonald 1952) was built. Although this proved to be satisfactory when dry rations were fed, the feeding of fresh grass and silages made the separation of faeces from urine difficult because of the high moisture content.

Dick and Mules (1954) have described equipment for the clean collection of urine and faeces from wether sheep using a urine funnel strapped to the animal. In this type of equipment the faeces is allowed to fall through a grid on which the animal stands and is collected in a special receiver attached to the floor of the crate. This type of faecal collection apparatus would not be suitable for faeces of very high moisture content and the only satisfactory system for the complete and clean collection of both faeces and urine is by bag and funnel. A new type of crate was therefore designed which would permit the clean collection of urine and faeces and would avoid food scatter and contamination. The design of the new type of crate can be seen in Figs. 3 - 6. The front of the crate is completely enclosed, the feeding boxes are lined with aluminium and water troughs are fixed to the sides of the crate. Each crate accommodates two sheep, the two being separated by a central partition of hard board except for a small wire mesh 'window' which enables the paired animals to see each other. It is undesirable/

Fig. 4.

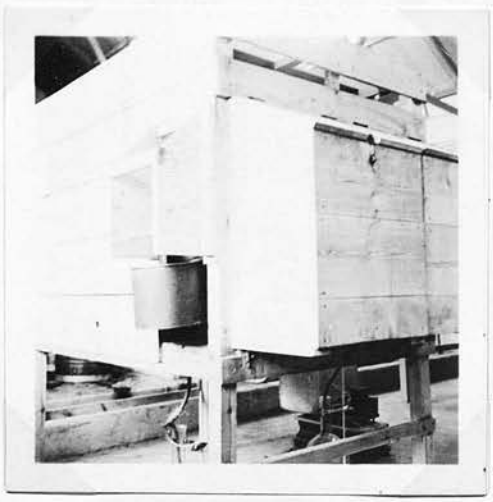


Fig. 5.

Fig. 6.

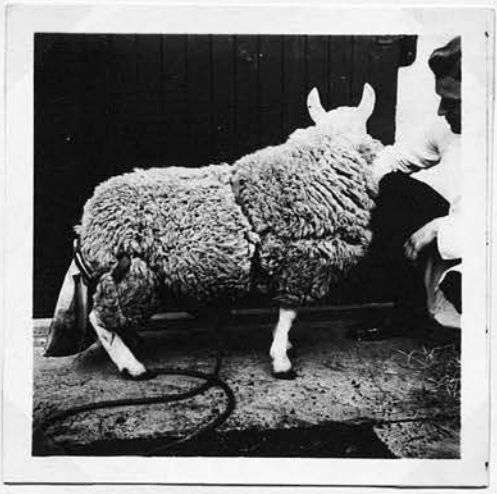


Fig. 7.

undesirable and unnatural for animals to be kept in isolation; in such an environment sheep are constantly restless and suffer from anorexia. The floor of the crate is constructed of wood and covered with a layer of 1/8" rubber sheeting except for a small slit through which the tube leading from the urine funnel passes into a 5 litre polythene receiver. The urine funnel is made of rubber and is held in position by means of two straps which encircle the animals body (Fig. 7). The bag for collecting faeces is made of reinforced rubber and contains a stiff metal ring held in position by a strap attached to the body harness (Fig. 7). By the simple process of unfastening a single buckle the bag can be very easily removed. In later experiments it was found more convenient to place a thin polythene bag inside the rubber bag in order to catch the faeces. By weighing the polythene bag empty and the following day with contents, a more accurate measure of total fresh faeces can be obtained. This system also eliminates the errors caused by transferring wet fresh faeces from the collection bag into a weighing receptacle. During the experiments the animals are held by means of a loose chain attached from the front of the crate to a leather collar. Sufficient freedom of movement is allowed to enable the animal to feed and rest in comfort.

This type of crate has proved satisfactory for metabolism studies and apart from the complete collection of both urine and faeces with wether animals, it has the advantage that food is not wasted by scattering during feeding.

(b)/

(b) Animals:- The same breed of animal was used throughout the experiments viz. half-bred wethers (Border Leicester X Cheviot ewe). Raymond and co-workers (1953, 1954) have stated "digestibility differences between animals are likely to be small compared with differences between batches of the same feed". In a number of experiments carried out by these workers using frozen herbage, hay and dried grass in order to compare the digestive abilities of sheep of different ages, regression analysis on the data obtained showed an average increase of about 1 unit of digestibility per year from lambs to 2 years olds. Although it is doubtful if this small difference is of much significance, during comparative trials in the present investigation animals of similar age were used; these were always within the age group 1 - 2 years. All experiments were carried out in duplicate.

(c) Experimental technique:- All the digestibility trials were of similar design consisting of a preliminary feeding period varying between 7-14 days. When new animals were used these were generally brought inside and housed in pens until accustomed to being handled, this period of "training" usually lasted from 4 - 8 weeks. Where a complete change of feeding occurred, e.g. from a silage diet to a hay diet, a preliminary feeding period of at least 14 days was allowed.

The experimental feeding period lasted 13 days and consisted of two five-day subperiods during which daily samples of feed were taken. These were dried separately then bulked in five-day lots for subsequent analysis.

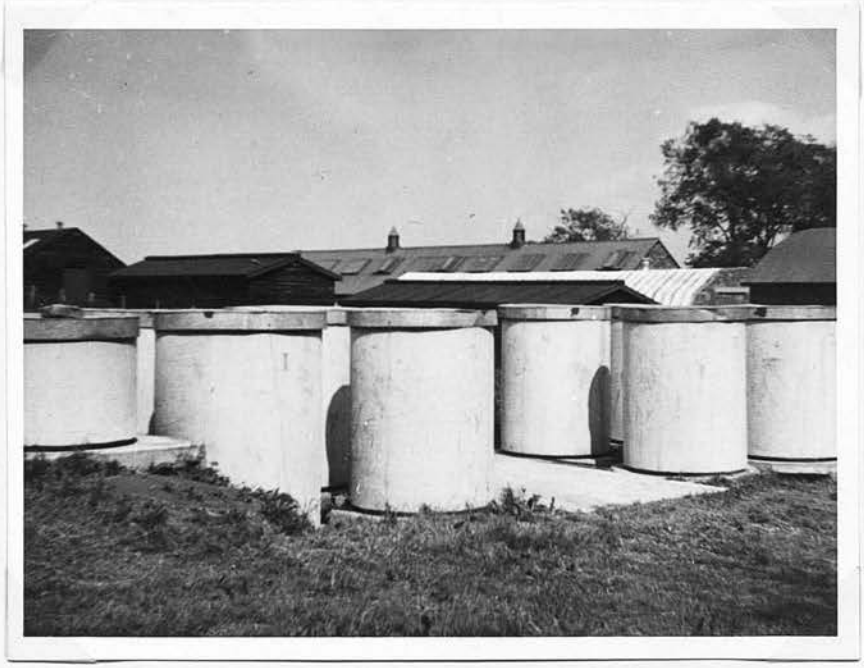
Where/

Where uneaten residues remained in the feeding boxes or on the floor of the crate these were weighed and if markedly different in composition from the original feed, analysed. Corresponding deductions were then made to the total feed intake figures in the calculation of the digestibility results.

Faeces were similarly collected over a 10-day period, there being a 3 day time-lag between commencement of feeding and the first collection of faeces. The daily faeces collection from each sheep was weighed, and after thoroughly mixing them a 10 per cent aliquot of the fresh faeces was kept at 0 - 4°C. These aliquots were bulked in 5 day sub-periods, thoroughly mixed and analysed for nitrogen. When losses of nitrogen occurred during drying the dry matter values were corrected calculating the volatile nitrogen as NH_3.

Part of these studies involved the measurement of losses of digestible nutrients during the ensilage process; it was therefore necessary to have some system of measuring the digestibility of the fresh grass ensiled. Probably the most successful method of doing this is to preserve sufficient grass on the day of ensiling by storage at low temperature. Unfortunately 'deep freeze' equipment was unavailable and the digestibility of the fresh grass was determined on samples of herbage cut daily from the area used for silage making for twelve days before filling the silos and for eight days subsequently. These samples were taken from random strips left in the field for this purpose. The analytical figures used for the calculation of digestibility data were obtained from grass samples taken five days before and five days after the date of ensiling.

Fig. 8.



(ii) Silage experiments

(a) Experimental silages.

The silos used in these experiments were of the concrete tower type (6 ft. x 4 ft.) and had an approximate maximum capacity of 750 Kg. of fresh herbage. In experiments 2 and 3 similar concrete tower silos were used but of smaller dimensions (3 ft. x 3 ft.) and capacity (190 Kg.). Each silo was provided with an outlet pipe for effluent collection and a tight-fitting galvanized metal roof (Fig. 8). In all experiments quantities of grass ensiled and silage removed were recorded and in addition effluents were collected and analysed as they appeared. During filling of the silos, samples of fresh grass were taken from each load and these were bulked prior to sub-sampling for analysis. Before replacing the roofs, the tops of the silos were covered with 'sisalkraft' paper and soil to a depth of about 6 in.

For the purpose of conserving the silage after opening the silos, the contents, after weighing and sampling were transferred to cylindrical metal bins (30 in. x 14 in.) The silage was consolidated in the bins which were then sealed with tight fitting lids. The silage was weighed out daily from these bins during digestibility trials.

(b) Farm silages.

A few samples of silages for digestibility studies were obtained from large farm silos. Three separate trials were carried out on farm silages and in each case the silo from which the material was obtained was of the 'trench' type. Silage was cut from the vertical face by means of a sharp hay knife and after sampling, was immediately consolidated in metal bins throughout the period of the trial, as described above.

(iii) Analytical Methods

(a) Sampling and dry matter estimations.

Fresh grass:- Daily samples of fresh grass were taken prior to feeding, dried for 24 hours at 100°C in a 'Mitchell-Graham' electric oven. These dried samples were milled through 1 mm. mesh sieve and stored in screw capped bottles until analysed.

Silage:- Owing to the losses of volatile constituents which occur during the drying of silage it is necessary to analyse fresh as well as dried samples in order that corrections can be made. During emptying of the silos, samples of silage were taken, well mixed, minced and 10 g. samples used for total nitrogen estimation. In addition 100 g. samples were taken for pH, lactic acid, acetic acid, butyric acid and 'dry matter' determinations. The dried silages were also analysed for total nitrogen, acetic and butyric acids. Loss of volatile nitrogen was expressed in terms of NH_3, this and losses of acetic and butyric acids during drying were added to the 'apparent dry matter' figure to give the 'true dry matter' (Appendix I Table No. 43). Since the amounts of volatile acids lost during drying would be included in an ether extract from fresh silage, it is common practice (Watson 1939; Brown and Heaney 1951) to correct the values for ether-extractable material obtained from dried silage for volatile acids lost, in addition to amending the dry matter figures. Such corrections have not been applied in this work for a number of reasons, and acetic acid and butyric acid lost on drying will therefore contribute to the values for nitrogen-free extractives. The bulk

of/

of the volatile fatty acids in silages can be ascribed to acetic acid or in the case of 'bad' silages to butyric acid, derived from carbohydrate included in the nitrogen-free extractives fraction; therefore the inclusion of the volatile acid lost on drying in the ether extractable material involves a transference of material to a different fraction, and complicates the problem of assessing losses of individual constituents in the silo. In addition, acetic acid does not possess the energy value of a fat, and its inclusion in the ether-extractable fraction would therefore falsify the results for starch equivalents and total digestible nutrients in silages.

Hay:- Prior to the commencement of the hay feeding trials, the hay was cut into small lengths by means of a chaff cutter, well mixed and daily rations weighed out into bags to provide sufficient food for both the preliminary and experimental feeding periods. This system not only ensured that representative hay samples were fed each day but also reduced the number of samples required for analysis to a minimum.

Faeces:- The only correction to the faeces dry matter value was for volatile nitrogen. Fresh faeces collected over five day periods and stored in the refrigerator were mixed, sampled and analysed for nitrogen and dry matter. Apart from these all other determinations were carried out on dried and milled faeces.

(b) Chemical analysis

Routine Analysis:- Crude protein (C.P.), ether extract (E.E.), crude fibre (C.F.), nitrogen-free-extractives (N.F.E.) and ash were determined by the/

the methods laid down in the Regulations of the Fertilisers and Feeding Stuffs Act (1932). The acetic and butyric acid contents of the silages were estimated by the Wiegner method and lactic acid was estimated by the method described by Smith (1938).

In addition to the usual estimations carried out on the silages, determinations of 'Normal Acid Fibre' (N.A.F.) and Laboratory 'Digestible Nutrients' (L.D.N.) were also made. The N.A.F. estimation was carried out as described by Raymond, Walker and Griffith (1953). The L.D.N. is based on a method described by Thurman and Wehunt (1955). These workers have stated that the treatment of a 1 g. sample of dried ground material with 1 ml. of conc. HCl and 19 ml. distilled water followed by autoclaving at 15 lb. pressure for 1 hour and neutralizing to methyl red with 20% NaOH dissolves a quantity of material which is similar to the T.D.N. value. This extract was designated Digestible Laboratory Nutrients (D.L.N.) and in an analysis of 10 different cereal silages was found to agree with the T.D.N. values reported by Morrison for foods similar to the materials used.

This method was tried out but found to be impracticable with silages because of the difficulty in neutralizing the dark extracts with NaOH; the method was therefore slightly modified, details being given in Appendix 3, and the determinations described as 'Laboratory Digestible Nutrients' (L.D.N.) which is considered a more appropriate term.

Carbohydrate estimations:- Total sugars were estimated (as glucose) in a 90 per cent alcohol extract (Wylam 1954) by the Somogyi method (1945) after clarification with equivalent volumes of $CdSO_4$ and NaOH (Laidlaw and Reid 1952)/

1952) and hydrolysis for four hours in a solution which was 0.5 N with respect to H_2SO_4. A correction was applied, as outlined by Wylam (1954), for fructose decomposition during hydrolysis.

Fructosan was determined (as fructose), after hydrolysis for 10 minutes at the same acid concentration, by the Somogyi method (Wylam 1954).

The sugars in the 'Normal sulphuric acid extract' were estimated (as glucose) by the method suggested by Harwood (1954). The extract was prepared by gently boiling the dried residue remaining after water extraction with 100 ml normal sulphuric acid, filtering through Whatman No. 54 and determining the sugars in the neutralised filtrate after a 4 hour hydrolysis in a solution which was normal with respect to H_2SO_4.

The sugars in the '72% sulphuric acid extract' were determined in the extract obtained by treating the dried residue, remaining after the normal acid extraction, with 72% sulphuric acid for 4 hours, diluting to normal and boiling under reflux for 2 hours, and filtering through an asbestos lined Gooch crucible. All extracts were neutralised with NaOH prior to Somogyi estimations. The residue from the above treatments was weighed, ignited and loss of organic matter designated 'insoluble organic residue'.

Comments.

One advantage of the above system is that the same sugar estimation can be applied to all the hydrolysed extracts. The Somogyi method was considered to be the most suitable method for reducing sugar estimation and has/

has the advantage that the conversion factors for the two main sugars produced i.e. - glucose and xylose are identical viz. 0.136. The reducing values of glucose, xylose and fructose were determined periodically during the estimations and did not vary more than 5% (Appendix 3).

Because of the necessity for hydrolysing the alcohol extract for 4 hours with sulphuric acid in order to convert the oligosaccharides into monosaccharide units (Wylam 1954) it is important to know to what extent the various sugars are destroyed by the acid during this process. Wylam (1954) has determined the stability of various sugars under hydrolytic treatment and has found that when glucose, galactose, fructose, xylose and arabinose were treated with (a) 0.5 N sulphuric acid, and (b) 1.5 N sulphuric acid only fructose was found to suffer decomposition. After 4 hours heating with 0.5 N H_2SO_4 Wylam recovered 73% of fructose. The complete recovery of glucose and xylose has been confirmed in this work under similar conditions: Table 3 shows the effect of 0.5 N sulphuric acid on fructose decomposition when heated under reflux in a boiling water bath for varying periods of time.

Table No. 3

Time of heating	Recovery of fructose %
10 mins.	98.08
20 mins.	93.80
30 mins.	91.38
1 hour	86.14
2 hours	77.87
3 hours	71.33
4 hours	68.33

The weight of fructose in the oligosaccharide portion can be determined by means of the Rae colorimetric estimation (Wylam 1954) and therefore the total/

total weight of oligosaccharides, correcting for 31.7% decomposition of fructose, can be calculated. Since chromatographic separation of the individual sugars was not carried out the reducing value was expressed in terms of glucose.

Most of the methods for the extraction of fructosan in herbage are based on a water extraction after removal of sugars by alcohol. Waite and Boyd (1953) have suggested boiling the alcohol-extracted residue with water for 30 minutes and whilst this method is a simple one, there seems to be no real evidence that a boiling water extract does not also remove pentosans. The differences between the Roe method, which is specific for fructose units and the Somogyi method after hydrolysis would seem to indicate from preliminary experiments that substances other than fructosan can be removed. Wylam has suggested a 12 hour, cold water, extraction and since Wylam showed that only a trace of araban was extracted under these conditions this method was adopted.

Harwood (1954) has found that a N-sulphuric acid treatment of grass for one hour at the temperature of a boiling water-bath dissolves all the galactose and arabinose polysaccharides leaving a residue containing only ash, protein, lignin, cellulose and xylan. The author found that the normal sulphuric acid solution contained xylose and glucose as well as considerable quantities of oligosaccharides. Further hydrolysis with N-acid eliminates the oligosaccharides after four hours at reflux temperature. The main components of the oligosaccharides were glucose and xylose. Harwood suggested that treatment with N-sulphuric acid degraded cellulose to glucose and glucose oligosaccharides/

oligosaccharides. Although this author did not investigate the extent of cellulose degradation, indications from studies for this thesis suggest that the extent of cellulose breakdown is likely to be small since recoveries of 95.0, 96.0 and 95.4% of filter paper cellulose were obtained after boiling for one hour with N-sulphuric acid in three separate experiments.

The residue after the N-sulphuric acid treatment contains ash, protein, lignin and polysaccharides hydrolysable to glucose and xylose only. Numerous investigators have studied the saccharification of such residues, the usual procedure being a primary hydrolysis at room temperature with 72% acid followed by a secondary hydrolysis at the boiling point after dilution to 3-5%.

Experiments carried out in this work in which glucose was treated with 72% H_2SO_4 at 20°C ± 2° for 4 hours followed by dilution to normal and boiling for 2 hours showed recoveries of 99.5; 100.3; 99.9 and 99.7 per cent in four separate experiments.

The main contaminant of lignin residues is protein and the majority of workers (Moon and Abou-Raya 1952; Thomas and Armstrong 1949) recommend either a pepsin digestion or a nitrogen correction on the final residue. In this work no predigestion nor nitrogen corrections were applied and hence the residue from the method is not considered to be a 'true lignin' value. The residue was ignited in the determination and the loss reported as 'insoluble organic residue'. Full details of these methods are given in Appendix 3.

Preliminary experiments in order to establish the reliability of this method of carbohydrate determination had been made on a number of different

samples/

samples. Duplicate results on samples obtained from a digestibility trial are given in Table 4.

TABLE 4

Extract	Hay		Faeces	
	(i)	(ii)	(i)	(ii)
(A) Alcohol (total sugars)	6.36	6.45	0.33	0.34
(B) Water (fructosan)	5.37	5.40	Nil	Nil
(C) N acid ext. sugars	15.20	15.09	16.97	17.13
(D) 72% acid ext. sugars	24.40	24.00	19.99	19.99
(E) Insoluble organic residue	8.23	8.12	19.82	20.03

Throughout the course of this work all analyses have been caried out in duplicate, the mean results being reported in the tables.

RESULTS AND DISCUSSION

(i) Effect of pH on the nutritive value of silages.

The purpose of these experiments was to compare the nutritive value of 'good' and 'bad' silages. For the purpose of distinguishing between badly preserved and well preserved silage, a pH value of 4.5 was taken as the dividing line.

(a) Farm silages.

Experiment No. 1

Samples of silage made from a grass-clover ley were taken from a farm 'clamp' silo on 25.2.53. At the time of sampling, the silage was approximately 6 feet in depth; samples were taken from the top three feet and stored separately from the material taken from the bottom three feet. Digestibility trials were carried out in duplicate on these two samples.

Detailed results of the trials are given in Appendix I (Tables 44 and 45) and the composition and digestibility data are summarised in Table 5. The pH values and organic acid contents are given in Table 6.

It can be seen that two entirely different types of preservation had occurred within the same silo. Another outstanding difference is reflected in the protein content, these being 11.52 and 18.00 per cent dry matter in the top and bottom silages respectively. The corresponding digestibility coefficients are 48.3 and 71.1. The difference in protein content can partly be explained by the fact that although the grass had been cut from the/

TABLE 5

Composition and digestibility of farm silages. Expt. No. I

	% Composition		Digestibility Coefficients				Digestible Nutrients	
	Silage from Top	Silage from Bottom	Silage from Top		Silage from Bottom		Silage from Top	Silage from Bottom
Dry matter	15.31	19.19	65.9, 66.2	66.1	63.7, 62.2	63.0	66.1	63.0
Organic matter	91.41	89.97	67.5, 67.4	67.5	64.0, 63.1	63.5	61.62	57.13
Crude protein	11.52	18.00	48.9, 47.6	48.3	71.1, 71.0	71.1	5.56	12.80
Ether extract	2.97	3.98	70.3, 69.1	69.7	67.4, 64.8	66.1	2.07	2.63
Crude fibre	34.51	35.69	76.4, 76.5	76.5	71.0, 69.5	70.3	26.38	25.10
N.F.E.	42.41	32.30	65.0, 65.3	65.2	51.4, 51.5	51.4	27.62	16.60
Ash	8.59	10.03	-		-		-	-
S.E.							53.2	45.9
T.D.N.							64.2	60.4

Table 6

Organic acid contents of silages. Expt. No. I

	pH	Acetic acid	Butyric Acid	Lactic acid
Silage from top of silo				
% Fresh	3.90	0.39	0.01	0.30
% Dry matter		2.55	0.07	1.96
Silage from bottom of silo				
% Fresh	5.25	0.16	0.87	0.05
% Dry matter		0.83	4.53	0.26

TABLE 7

Nitrogen Balance. (10 day period). Expt. No. I

	Urine			Food	Faeces	Balance of	% Dig. N. retained
	Volume (ml.)	% N	Wt. N.g.	N.g.	N.g.	N	
1. Silage from top of silo							
Sheep N. 1.	9,920	0.27	26.8				
2.	11,380	0.23	26.4				
Total	21,300		53.2	165.6	84.9	27.5	34.94
Sheep O. 1.	12,820	0.22	28.3				
2.	13,835	0.19	26.3				
Total	26,655		54.6	165.0	86.9	23.5	30.08
2. Silage from bottom of silo							
Sheep P. 1.	11,755	0.47	55.0				
2.	16,240	0.42	67.6				
Total	27,995		122.6	254.6	72.8	59.2	32.56
Sheep Q. 1.	12,390	0.46	57.2				
2.	13,260	0.49	65.2				
Total	25,650		122.5	253.5	73.1	57.9	32.10

the same field, the cutting and ensiling process had extended over a three week period resulting in a more mature type of material being preserved at the top of the silo. The differences in maturity, however, although indicated in the protein content, are not reflected in the crude fibre figures, which suggests that the variation in composition may not be solely due to the maturity factor.

The nitrogen balance data are shown in Table 7 and it is interesting to note that a greater quantity of nitrogen was retained by the animals consuming the high nitrogen silage although the percentage utilization of the digestible nitrogen figures for the four sheep show little significant difference.

This experiment does illustrate the variations which can occur within the same silo when silage is made under farming conditions and also confirms the difficulties encountered in obtaining a representative sample of silage from a large silo. It was for this reason that it was decided to confine all future experiments to silage made in the Boghall experimental silo units.

(b) Experimental silages

Experiment No. 2

Silages were obtained from 4 of the small experimental silos (dimensions 3 ft. x 3 ft. capacity 190 Kg. grass) at Boghall. These silages had been made by the Bacteriology department in May 1953 from a high protein grass-clover mixture, the treatments being as follows:-

Silo/

TABLE 8

Composition and digestibility of silages from Boghall small silos. Expt. No. 2

	% Composition		Digestibility Coefficients		Digestible Nutrients	
	Silage from silos 15 16	Silage from silos 13 14	Silage from silos 15 16	Silage from silos 13 14	Silage from silos 15 16	Silage from silos 13 14
Dry matter	21.15	13.46	78.3, 77.3 → 77.8	73.2, 76.2 → 74.7	77.8	74.7
Organic matter	91.37	89.46	82.0, 80.8 → 81.4	79.1, 81.4 → 80.3	74.38	71.84
Crude protein	23.21	23.06	81.2, 80.9 → 81.1	79.2, 82.1 → 80.7	18.82	18.61
Ether extract	6.65	5.55	70.3, 68.4 → 69.4	63.3, 68.0 → 65.7	4.62	3.65
Crude fibre	28.40	28.95	88.3, 87.4 → 87.9	86.8, 88.7 → 87.8	24.96	25.42
N.F.E.	33.11	31.90	79.6, 77.6 → 78.6	74.7, 76.6 → 75.7	26.02	24.15
Ash	8.63	10.54	-	-	-	-
S.E.					69.2	65.7
T.D.N.					80.2	76.5

TABLE 9

Organic acid contents of silages. Expt. No. 2

	Mean pH	Acetic acid	Butyric acid
1. Silage from silos 15 and 16			
% Fresh	4.4	0.19	Nil
% Dry matter		0.90	Nil
2. Silage from silos 13 and 14			
% Fresh	4.9	0.26	Nil
% Dry matter		1.93	Nil

Silo No. 13 Lactobacillus inoculation only.

Silo No. 14 Control, not inoculated.

Silo No. 15 Lactobacillus inoculation and heavily weighted with stones (2,321 lb.)

Silo No. 16 Not inoculated, but weighted with stones (2,321 lb.)

The silos were opened on 2nd and 4th September, 1953, the respective pH values for these silages being 4.86, 4.76, 4.22 and 4.58. Since there was insufficient material for digestibility studies from individual silos, it was necessary to bulk two treatments together. Silage from silos 13 and 14 were bulked giving a resulting pH value of 4.9 and silage from 4·8 silos 15 and 16 were bulked giving a resulting pH value of 4.4. The silages were stored in metal bins in the usual way and two separate digestibility trials, with duplicate sheep, were carried out on the bulked material.

Although detailed analytical data were not available for the effluents, the volumes from silos 15 and 16 were measured and these were 92.6 litres and 79.5 litres respectively. No effluents were produced from the unweighted silos.

It can be seen from the dry matter figures in Table 8 that the effect of consolidating the herbage with heavy weights had caused considerable flow of water from the mass although the percentage composition of the different silages on a dry matter basis showed little variation. The digestibilities of the organic constituents are also similar and there is no apparent difference in nutritive value of the silages.

The/

TABLE 10

Nitrogen Balance. Expt. No. 2

	Urine			Food	Faeces	Balance of N	% Dig. N. retained
	Volume (ml.)	% N	Wt. N.g.	N.g.	N.g.		
1. Silage from silos 15 and 16							
Sheep P. 1.	21,930	0.65	143.4				
2.	24,850	0.65	160.5				
Total	46,780		303.9	392.8	73.7	15.09	4.73
Sheep Q. 1.	17,000	0.94	160.0				
2.	15,800	1.01	160.0				
Total	32,800		320.0	392.8	75.2	- 2.11	- 0.66
2. Silage from silos 13 and 14							
Sheep P. 1.	30,280	0.53	160.8				
2.	28,500	0.54	154.8				
Total	58,780		315.5	339.0	70.6	-47.1	- 17.5
Sheep Q. 1.	25,650	0.55	141.6				
2.	24,160	0.61	146.9				
Total	49,810		288.5	339.0	60.8	- 10.28	- 3.7

The nitrogen balance data are shown in Table 10; it is rather surprising to note the high rate of excretion of nitrogenous substances in the urine and it would appear that the nitrogenous substance in the silages are not being utilized as a source of body protein. However in this particular experiment it would be unwise to conclude that this is the possible explanation since the dry matter intake of sheep P in the second experiment was only 885 g. per day (Appendix I Table 46) and in spite of the relatively high S.E. value of this silage it is possible that the energy requirement for maintenance and the actual intake of energy were sufficiently close to cause the animal to utilize body protein as an energy source. Because of this possibility it would be unwise to attach too much significance to the negative balance figures obtained.

Experiment No. 3

A similar experiment was carried out in an attempt to produce a 'good' and a 'bad' silage from similar material. In this case a medium-high protein (16.23%) grass was ensiled in four of the small silos the only difference in treatments being the addition to two of Lactobacillus culture at the time of filling. The inoculum diluted with 2 gallons water was added to silos 11 and 12 in the form of a fine spray. The other two silos (Nos. 13 and 14) were sprayed in a similar manner with an equal volume of pure water. The herbage in all four silos was consolidated, covered with 'sisalkraft' paper and soil and roofed in the usual way. The treatments were therefore duplicated, although the silages from similar/

Table 11

Composition and digestibility of silages from Boghall small silos. Expt. No. 3

	% Composition		Digestibility Coefficients		Digestible Nutrients	
	Silage from silos 11 12	Silage from silos 13 14	Silage from silos 11 12	Silage from silos 13 14	Silage from silos 11 12	Silage from silos 13 14
Dry matter	15.17	15.71	72.7) 74.5) 73.6	75.8) 75.3) 75.6	73.6	75.6
Organic matter	85.76	85.97	77.5) 79.3) 78.4	80.5) 80.1) 80.3	67.17	69.03
Crude protein	17.96	17.76	73.4) 75.1) 74.3	76.8) 76.3) 76.6	13.34	13.60
Ether extract	2.60	2.30	44.6) 39.2) 41.9	44.0) 51.9) 48.0	1.09	1.10
Crude fibre	21.33	22.80	82.6) 85.8) 84.2	86.9) 85.0) 86.0	17.96	19.61
N.F.E.	43.78	43.11	78.6) 80.1) 79.4	80.6) 80.6) 80.6	34.76	34.75
Ash	14.33	14.89	-	-	-	-
S.E.					61.1	62.6
T.D.N.					68.5	70.4

Table 12

Organic acid contents of silages. Expt. No. 3

	pH	Acetic acid	Butyric acid	Lactic acid
1. Silage from silos 11 and 12				
% Fresh	4.0	0.34	Nil	1.65
% Dry matter		2.26	Nil	10.87
2. Silage from silos 13 and 14				
% Fresh	4.6	0.48	0.02	1.28
% Dry matter		3.06	0.10	8.15

similar treatments were bulked prior to commencement of digestibility trials. The silos were filled on 9th October, 1953 and opened on 22nd April, 1954.

The pH values and organic acid contents of the silages are shown in Table 12 and it can be seen that there is a pH difference of 0.6 units. The silage from silos 11 and 12 was well preserved and could be classed as a 'good' silage. The pH value of the silage from silos 13 and 14 is above 4.5 and although a trace of butyric acid (.02%) was present, the silage could not be designated a very 'bad' silage.

The composition and digestibility data are given in Table 11 and although the poorer preserved material shows slightly higher digestibility coefficients for all constituents it is doubtful if any significance could be attached to these small differences.

The nitrogen balance results are given in Table 13 and again the silage from silos 13 and 14 shows rather higher values although in view of the variation between sheep T and U there is probably little significance in this finding except to conclude that the higher pH silage is utilized as well as the well preserved material in spite of the greater percentage of volatile nitrogenous substances (Appendix I Table 43). The volatile nitrogen figures for the 'good' and 'bad' silages expressed as percent NH_3, were 0.040 and 0.073 respectively.

During the ensilage process complete records of effluent volume and composition were kept and these are shown in Appendix I (Table 51). In spite of the relatively high moisture content (82.74%) of the original grass

the/

TABLE 13

Nitrogen Balance. Expt. No. 3

		Urine			Food	Faeces	Balance of N	% Dig. N. retained
		Volume (ml.)	% N	Wt. N.g.	N.g.	N.g.		
1. Silage from silos 11 and 12								
Sheep R.	1.	13,390	0.44	58.7				
	2.	12,495	0.47	58.9				
Total		25,885		117.6	230.8	61.9	51.4	30.4
Sheep S.	1.	14,660	0.40	58.8				
	2.	12,540	0.47	59.3				
Total		27,200		118.1	223.5	56.2	49.2	29.4
2. Silage from silos 13 and 14								
Sheep T.	1.	12,730	0.47	58.8				
	2.	12,670	0.45	57.5				
Total		25.400		116.3	232.5	50.1	66.1	36.2
Sheep U.	1.	16,130	0.41	66.5				
	2.	14,655	0.42	62.1				
Total		30,785		128.6	242.7	53.4	60.7	32.1

TABLE 14

Summary of % losses during ensilage process. Expt. No. 3

	⁑ Silage from silos 11 and 12	* Silage from silos 13 and 14
Dry matter	12.45	10.43
Organic matter	14.62	10.91
Crude protein	3.13	1.94
Ether extract	41.15	46.74
Crude fibre	14.62	6.61
N.F.E.	16.46	15.85

⁑ Including losses in effluent. Dry matter 0.76%. Nitrogen 1.34%.

* Including losses in effluent. Dry matter 0.44%. Nitrogen 0.68%

the losses of dry mattervia this source are extremely low, the maximum from silo 11 being only 0.25 Kg. It can also be seen from this table that the loss of nitrogen via the effluent is also of a low order.

The losses which occurred during ensilage have been calculated and these are shown in Table 14. The total % dry matter losses for the inoculated and the control silages were 12.45 and 10.43 respectively. The loss of crude fibre from the inoculated herbage was much higher (14.62%) than from the control (6.61%). This loss of fibre which occurred in the inoculated material is quite high and would indicate that this constituent can be broken down during ensilage. Losses of crude fibre during the ensiling proces have also been reported by Watson (1939).

Discussion

The difficulties in carrying out experiments on silages taken from farm silos can be seen from the results obtained in experiment 1. Under normal farming conditions, it is necessary for the process of ensiling to extend over a number of days and even weeks which results in a mixture of herbage of varying chemical composition and stage of growth being present in the same silo. This factor alone makes comparison of silage samples of different pH values from the same silo difficult. It is obvious that in order to determine the effect of pH upon nutritive value it is necessary to compare silages made from grass of similar composition and the importance of using small silos for this purpose is obvious.

It is generally agreed that silages of high butyric acid content, a factor which is normally associated with 'bad' silages, are more frequently produced from high protein herbage than from low protein material, unless carbohydrates in the form of molasses are added in order to stimulate lactic acid production. In experiment 2, the original grass from which the silages were made was of a very high protein content, but in spite of this, the highest pH value produced was only 4.9 and butyric acid was absent. It is interesting to note that Blish (1924) puts the danger point for butyric acid fermentation at pH 4.9; and to avoid its presence this worker states that a greater acidity must be aimed at. Virtanen (1934) has stated that the butyric acid bacilli cease growth at pH 4.2 and the control of the butyric fermentation by the lactic acid organisms which can grow under acid conditions is, therefore, clearly due to the acidity produced by them.

Probably too much importance in the past has been attached to the presence of butyric acid in silage largely because of its unpleasant and clinging smell. There is no evidence that butyric acid material is unpalatable to stock and as a source of energy, this acid has higher calorific values that both acetic and lactic acids. Butyric acid, however, results from bacterial activity on lactic acid and is usually produced some time after the initiation of the fermentation. According to Barnett (1954), the happenings can be crudely represented thus:

$$\underset{\text{Lactic acid}}{2C_3H_6O_3} \longrightarrow 2H_2 + 2CO_2 + \underset{\text{Butyric acid.}}{C_4H_3O_2}$$

It/

It is also possible however for butyric acid to be produced by direct action of saccharolytic organisms on disaccharides:-

$$C_{12}K_{22}O_{11} + H_2O \longrightarrow 2C_6H_{12}O_6 \longrightarrow 4H_2 + 4CO_2 + 2C_4H_8O_2$$

Butyric acid.

It follows therefore that in spite of the higher energy value of butyric acid over either of its precursors, apart from other factors, the loss of energy which occurs during its formation is sufficiently great to more than offset the higher calorific value of the final product.

In each of these three experiments the silages with high pH values have also contained high amounts of volatile nitrogenous constituents. This relationship between volatile nitrogen and pH value has been shown by Watson (1939). Breakdown of protein during ensilage is generally regarded as being deleterious although in view of the complexity of the microbiological reactions which occur in the rumen, this may not necessarily be so. Chalmers and co-workers (1954) have demonstrated the formation of ammonia from protein of different foods by the rumen flora; the extent of utilization of ammonia and other simple nitrogenous constituents by these microorganisms depends upon many factors of which the presence of easily fermentable carbohydrates is one. The results of nitrogen balance data in experiment 1 indicate that the nitrogenous constituents in the high pH silage are being as well utilized as those in the lower pH material, and the results of experiment 3 also confirm this fact. It would seem from this that partial protein breakdown during ensilage is not necessarily wasteful provided the products do not reach the putrefactive stage./

stage. However despite the results indicated from these experiments viz. there is little difference in nutritive value between silages of different pH made from similar herbage, the unpleasantness associated with handling butyric acid silage and the possibility of toxic products being produced at high pH levels make it desirable to preserve material at a pH of less than 4.5, when silage is made by the ordinary process.

Summary

The three experiments described are attempts to obtain different kinds of preserved herbage from similar grass. The results indicate the danger in carrying out experiments of this type on silages produced from farm silos, owing to the possible variations which can exist throughout the mass. Because of the necessity of filling a large silo over a period of days the variation in chemical composition of herbage going into the silo can be considerable and introduces a variable factor, which seriously interferes with the interpretation of the results. For this reason it was decided that future experiments would be conducted in small experimental silos of maximum fresh grass capacity 750 Kg. Two experiments carried out using small silos were successful in producing differently preserved material in each case, although the poorer preserved materials could not be classified as being very 'bad' silages, since butyric acid was either absent or present in small amounts. In the silages which were produced there appeared to be little difference in nutritive value between the high and low pH products.

(ii) Effect of wilting on the nutritive value of silages

The purpose of these experiments was to study the effect of partial wilting of fresh grass prior to ensiling, upon the nutritive value of the resulting product.

(a) Grass wilted for 22½ hours.

Experiment No. 4

In this experiment the digestibility of the fresh grass was determined on samples of herbage cut daily from the area used for silage. The analytical figures used for the calculation of digestibility data were obtained from grass samples taken five days before and five days after the date of ensiling.

The grass-clover herbage was obtained from Boghall Farm and was cut on 4th June, 1953. The 750 Kg. capacity tower silos were used for this experiment; one silo was filled from material cut and immediately ensiled, while the other silo was filled with material which had been allowed to wilt in the field for 22½ hours prior to ensiling. During this period of wilting, no rain fell although the air was cool with no wind and the sky overcast. An area of the field was also cut and made into hay. This was made under ideal weather conditions and 7 days after cutting on the 11th June, the hay had dried sufficiently for stacking indoors. Digestibility trials were then carried out. The silos were emptied on 8th March, 1954 and digestibility trials were carried out on the resulting silages.

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TABLE 15

% Composition of fresh grass fed to sheep. Expt. No. 4

Grass	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash
Sample 1	20.0	87.79	12.98	2.15	25.22	47.44	12.21
2	18.9	88.98	12.83	2.66	25.65	47.84	11.02
3	18.7	91.05	13.98	2.50	24.49	50.08	8.95
4	20.5	92.03	13.44	2.85	23.96	51.78	7.97
5	20.0	91.77	14.95	2.85	24.64	49.33	8.23
6	21.5	92.69	12.66	2.50	22.97	54.56	7.31
7	20.2	92.59	12.90	2.91	23.72	53.06	7.41
8	16.5	92.78	13.34	2.83	25.74	50.87	7.22
9	20.9	93.59	12.55	2.99	25.42	52.63	6.41
10	20.5	92.79	10.49	2.24	24.14	55.92	7.21
Mean	19.8	91.60	13.01	2.65	24.58	51.36	8.40

TABLE 16

% Composition and digestibility of grass, hay and silages. Expt. No. 4.

	% Composition				Digestibility Coefficients				Digestible Nutrients			
	Grass	Hay	Silages		Grass	Hay	Silages		Grass	Hay	Silages	
	Fresh		Wilted	Fresh			Wilted	Fresh			Wilted	Fresh
Dry Matter	18.50	86.95	23.98	17.65	73.0) 76.5) 74.8	66.4) 65.0) 65.7	74.7) 75.9) 75.3	75.6) 75.4) 75.5	74.8	65.7	75.3	75.5
Organic Matter	91.55	90.26	90.77	90.90	75.6) 78.8) 77.2	67.8) 66.8) 67.3	76.9) 78.1) 77.5	78.1) 77.9) 78.0	70.68	60.74	70.34	70.90
Crude protein	12.88	14.43	15.57	14.07	67.2) 70.6) 68.9	65.0) 60.9) 63.0	76.4) 76.2) 76.3	76.1) 75.9) 76.0	8.87	9.09	11.88	10.69
Ether extract	1.92	1.99	3.67	2.54	65.5) 66.1) 65.8	41.7) 33.7) 37.7	72.4) 69.6) 71.0	65.2) 58.4) 61.8	1.26	0.75	2.61	1.57
Crude fibre	27.69	32.01	27.37	28.31	75.0) 78.1) 76.6	75.6) 75.9) 75.8	78.9) 80.0) 79.5	79.7) 80.5) 80.1	21.21	24.26	21.76	22.68
N.F.E.	49.06	41.83	44.16	45.98	78.4) 81.8) 80.1	64.1) 63.1) 63.5	76.2) 78.3) 77.3	78.5) 78.0) 78.3	39.30	26.56	34.14	36.00
Ash	8.45	9.74	9.23	9.10	-	-	-	-	-	-	-	-
S.E.									62.4	42.2	62.7	62.1
T.D.N.									72.2	61.6	73.6	72.9

The composition of the fresh grass is given in Table 15. It can be seen that there are day to day variations in all the constituents examined. The protein content fluctuates widely showing a minimum value of 10.49 per cent on the 10th day and a maximum value of 14.95 per cent on the 5th day. This variation corresponds to a difference of 16.1 per cent. The crude fibre content shows a tendency to vary inversely with the protein content. Details of the digestibility trial results are given in Appendix I (Tables 52 - 56); the results are summarized in Table 16, the figures in this table referring to the composition of grass having been obtained from a representative sample of the herbage taken at the time of ensiling the fresh grass. It can be seen from Tables 15 and 16 that the analytical figures for the composition of the ensiled fresh grass agree fairly well with the mean figures obtained for the composition of the grass during the 10 day trial, the only difference of any significance being shown in the crude fibre figures which for the ensiled grass and the trial grass are 27.69 and 24.58 respectively. The corresponding crude protein figures are 12.88 and 13.01. It can be seen from Table 16 that the protein contents of the hay and both silages are higher, on a dry matter basis, than the original fresh grass. With the exception of the ether extract, which because of its low value is of little significance, there is practically no difference between the digestibility coefficients of the two silages. Both silages compare favourably with the original fresh grass and the crude protein fraction is more digestible in the silages than in the fresh grass. It would appear from this that the ensiling process had slightly increased the digestibility/

TABLE 17

Organic acid contents of silages. Expt. No. 4

	pH	% Acetic acid	% Butyric acid	% Lactic acid
1. Wilted grass silage				
% Fresh	4.2	0.166	0.069	1.28
% Dry matter		0.692	0.288	5.34
2. Fresh grass silage				
% Fresh	3.7	0.590	Nil	1.39
% Dry matter		3.343	Nil	7.88

TABLE 18

Nitrogen Balance. Expt. No. 4

		Urine			Food	Faeces	Balance of N	% Dig. N. retained
		Volume (ml.)	% N	Wt. N.g.	N.g.	N.g.		
1. Fresh grass								
Sheep P.	1.	13,910	0.542	75.4				
	2.	13,825	0.482	66.6				
	Total	27,735		142.0	250.4	82.1	26.2	15.6
Sheep Q.	1.	10,680	0.725	77.4				
	2.	10,070	0.596	60.0				
	Total	20,750		137.4	250.4	73.6	39.3	34.8
2. Hay								
Sheep N.	1.	7,820	1.104	86.3				
	2.	5,700	1.000	57.4				
	Total	13,520		143.7	210.0	73.6	- 7.3	- 5.4
Sheep O.	1.	5,150	1.351	69.6				
	2.	4,575	1.410	64.5				
	Total	9,725		134.1	210.0	82.2	- 6.3	- 4.9
3. Wilted grass silage								
Sheep N.	1.	17,900	0.608	108.7				
	2.	14,600	0.591	86.2				
	Total	32,500		194.9	389.0	92.0	102.1	34.4
Sheep O.	1.	13,180	0.616	81.2				
	2.	12,560	0.582	73.2				
	Total	25,740		154.4	389.0	92.5	142.1	47.9
4. Fresh grass silage								
Sheep P.	1.	22,450	0.386	86.6				
	2.	21,260	0.390	83.0				
	Total	43,710		169.6	351.7	84.0	98.1	36.6
Sheep Q.	1.	20,870	0.436	91.4				
	2.	23,690	0.412	97.6				
	Total	44,560		189.0	351.7	84.6	78.1	29.2

digestibility of the nitrogenous substances. The hay shows lower digestibility values for all constituents except crude fibre which is equally as digestible as the fibre in the original grass.

It can be seen from Table 17 that both silages were well preserved, the wilted grass silage having a slightly higher pH value than the fresh grass silage, and containing a small quantity of butyric acid.

The results for the nitrogen balances are given in Table 18. Unfortunately because of differences in composition of materials fed the dietary intakes of nitrogen in the grass, hay and silage trials were not identical and for this reason it is difficult to compare directly the % balance figures in the last column. The agreement between the duplicate sheep is not good and it is doubtful if much significance can be attached to the results except to conclude that the nitrogenous substances in the silages are fairly well utilized. The negative balance figures for the hay are interesting, although the intakes of digestible energy by these animals were low because of the low dry matter intakes (Appendix I Table 53). This may be the explanation for the negative values.

In addition to the usual analysis, carbohydrates were determined by the methods described earlier. The results of these analyses are shown in Table 19. The total sugar content of the wilted grass silage is more than double that of the fresh grass silage, the normal sulphuric acid extract is slightly higher (14.72%) and the 72% acid extract rather lower (24.04%) in the wilted material. It can be seen from the digestibility data that more than 96 per cent of the total sugar in the silage has disappeared/

TABLE 19

Carbohydrate constituents in silage — Expt. No. 4.

	Total sugars	Fructosan	N. H_2SO_4 extract	72% H_2SO_4 extract	Organic residue
1. Wilted grass silage	3.39	0.295	14.72	24.04	6.66
Faeces					
Sheep N.	0.234	0.199	14.76	17.04	20.31
Sheep O.	0.307	0.196	14.39	15.72	20.40
Dig. Coefficients					
Sheep N.	98.3	82.8	75.0	82.3	29.9
Sheep O.	97.8	83.8	76.7	84.4	27.1
Mean	98.1	83.3	75.9	83.4	28.5
Dig. Nutrients					
Mean	3.33	0.246	11.17	20.05	1.90
2. Fresh grass silage	1.53	0.280	13.13	26.2	6.98
Faeces					
Sheep P.	0.229	0.157	14.68	16.39	21.28
Sheep Q.	0.176	0.170	14.89	15.44	21.82
Dig. Coefficients					
Sheep P.	96.3	86.3	72.7	84.7	25.5
Sheep Q.	97.2	85.1	72.1	85.5	23.1
Mean	96.8	85.8	72.4	85.1	24.3
Dig. Nutrients					
Mean	1.48	24.02	9.51	22.30	1.70

TABLE 20 Expt. No. 4.

Summary of % losses during ensilage process

	Wilted grass Silage	*Fresh grass Silage
Dry matter	13.77	14.09
Organic matter	14.87	14.70
Crude protein	+ 6.56	6.13
Ether extract	+40.74	+13.44
Crude fibre	18.05	12.17
N.F.E.	21.14	25.64

* Including losses in effluent. Dry matter 2.56%
Nitrogen 4.07%

disappeared during the passage of the food through the tract. The fructosan digestibilities are also high, although the quantities of this carbohydrate remaining in the silage after the preservation process are of a very low order. It is interesting to note the higher digestibility figures for the 72 per cent acid extract than for the N acid extract. Although the main component of the organic residue is lignin, this residue shows mean digestibility coefficients of 28.5 and 24.3 for the wilted and fresh grass silages respectively.

The losses occurring during ensilage have been calculated and these are shown in Table 20. The dry matter losses were of a similar order for the two silages viz. 13.77 for wilted material and 14.09 for fresh material. About 50 litres of effluent were obtained from the fresh grass silo, the analysis of this is given in Appendix I (Table 58). The dry matter lost in the effluent amounted to 18 per cent of the total dry matter loss from the silo. No effluent was produced from the silo containing the wilted material.

(b) Grass wilted for 8 hours.

Experiment No. 5

The previous experiment was repeated the following year, the difference being that the wilted grass was left in the field for only 8 hours before ensiling instead of for 22½ hours. The grass to be wilted was cut in the early morning and ensiled in the afternoon. During the period of wilting the weather was cool, windy and the sky overcast. No rain fell. The herbage/

TABLE 21

Composition and digestibility of silages from Boghall large silos. Expt. No. 5.

	% Composition		Digestibility Coefficients		Digestible Nutrients	
	Wilted grass Silage	Fresh grass Silage	Wilted grass Silage	Fresh grass Silage	Wilted grass Silage	Fresh grass Silage
Dry matter	23.71	18.72	77.3, 75.5 → 76.4	77.1, 67.1 → 69.1	76.4	69.1
Organic matter	88.26	88.09	80.9, 79.6 → 80.3	75.7, 75.3 → 75.5	70.87	66.51
Crude protein	12.15	11.99	67.2, 67.2 → 67.2	61.8 → 58.6	8.16	7.03
Ether extract	3.23	3.44	74.9, 81.4 → 78.2	75.3, 73.6 → 74.5	2.53	2.56
Crude fibre	29.31	29.93	87.1, 86.9 → 87.0	81.5, 83.6 → 82.6	25.50	24.72
N.F.E.	43.57	42.73	81.0, 77.9 → 79.5	75.5, 75.2 → 75.4	34.64	32.22
Ash	11.74	11.91	-	-	-	-
S.E.					62.6	58.2
T.D.N.					74.0	69.7

Table 22

Organic acid contents of silages. Expt. No. 5.

	pH	% Acetic Acid	% Butyric Acid	% Lactic acid
1. Wilted grass silage				
% Fresh	4.0	0.831	Nil	2.41
% Dry matter		3.504	Nil	10.16
2. Fresh grass silage				
% Fresh	3.9	0.800	Nil	1.88
% Dry matter		4.274	Nil	10.04

herbage was obtained from Boghall Farm and was similar to that used in Experiment 6. Details of the composition and digestibility of the fresh grass and the hay made from it are given under this later experiment.

The grass for the two silages was cut on 1st June, 1954. The silos were opened on 14th January, 1955 and digestibility trials carried out in the usual way. It can be seen from Table 21 that the composition of the two silages, on a moisture-free basis, is similar. The digestibilities, however, are higher in the wilted material than in the fresh grass silage and it would appear that the differences in protein digestibility are significant. The S.E. and T.D.N. values of the wilted grass silage are also higher than in the ordinary silage. Table 22 compares the organic acid contents of the silages, it can be seen that both silages were well preserved and the pH values are much closer than in the previous experiment. This finding is an exception to the generally accepted belief that wilted grass silage is necessarily of a much higher pH value than non-wilted material.

Nitrogen balance results are given in Table 23; because of the differences in dry matter contents of the two silages it was difficult to regulate the intake of food in order to ensure that all animals consumed similar amounts of nitrogen; in spite of this the large differences in balance figures suggest that nitrogen of fresh grass silage is not being as well utilized as in the wilted material.

The various carbohydrate fractions were analysed (Table 24). The percentage composition of these constituents was of a similar order as in the previous experiment, the main difference being a slightly higher total

sugar/

TABLE 23

Nitrogen Balance. Expt. No. 5

	Urine			Food	Faeces	Balance of N	% Dig. N. retained
	Volume (ml.)	% N	Wt. N.g.	N.g.	N.g.		
1. Wilted grass silage							
Sheep T. 1.	9,140	0.440	40.2				
2.	7,700	0.526	40.5				
Total	16,840		80.7	184.4	60.6	43.1	34.8
Sheep U. 1.	11,765	0.379	44.6				
2.	10,075	0.442	44.6				
Total	21,840		89.2	184.4	60.5	34.7	28.0
2. Fresh grass silage							
Sheep R. 1.	14,105	0.291	41.1				
2.	11,880	0.361	42.9				
Total	25,985		84.0	145.9	55.8	6.1	6.8
Sheep S. 1.	12,390	0.298	36.9				
2.	10,580	0.328	34.7				
Total	22.970		71.6	142.1	63.5	7.0	8.9

TABLE 24

Carbohydrate constituents in silages. Expt. No. 5

	Total sugars	Fructosan	$N.H_2SO_4$ extract	72% H_2SO_4 extract	Organic residue
1. Wilted grass silage	2.092	0.371	12.87	23.37	6.01
Faeces					
Sheep T.	0.166	0.247	12.12	8.78	24.75
Sheep U.	0.136	0.229	11.87	8.73	24.30
Dig. Coefficients					
Sheep T.	98.2	84.9	78.6	91.5	6.18
Sheep U.	98.4	84.9	77.4	90.9	0.99
Mean	98.3	84.9	78.0	91.2	3.59
Dig. Nutrients					
Mean	2.056	0.315	10.04	21.31	0.22
2. Fresh grass silage	1.458	0.224	12.38	23.66	6.39
Faeces					
Sheep R.	0.178	0.156	13.13	11.74	22.23
Sheep S.	0.133	0.157	13.09	10.45	22.25
Dig. Coefficients					
Sheep R.	96.5	79.9	69.4	85.7	- 0.41
Sheep S.	97.2	78.8	68.0	86.7	-5.24
Mean	96.9	79.3	68.7	86.2	- 2.83
Dig. Nutrients					
Mean	1.413	0.178	8.51	20.39	Nil

sugar value for the wilted grass silage in Experiment 5. The digestibility coefficients for the total sugars, fructosan and N acid extract are similar to those obtained in the previous experiment with the exception of the value for the N acid extract in the fresh grass silage which is significantly lower than that in the wilted material. The digestibility of the 72 per cent acid extract from the wilted silage is very high (91.2). In the previous experiment digestibility coefficients for the organic residues were 24.3 and 28.5 for the fresh and wilted materials; in this experiment the corresponding values are -2.83 and 3.59.

The losses which occurred during the ensilage process are shown in Table 25. Dry matter losses are again similar for the two silages although slightly lower than in the previous experiment. The high positive values for the ether extract fraction are due to the inclusion in this estimation of some of the acids produced during bacterial fermentation; fortunately the values are of a low order otherwise the results would falsify the Starch Equivalent and Total Digestible Nutrient figures.

In the fresh grass silage experiment 22 per cent of the dry matter lost can be accounted for in the effluent. Some 40 per cent of the crude protein lost in this experiment was recovered in the effluent. In the case of the wilted material no effluent was produced, and the amount of crude protein lost, per unit value of dry matter ensiled, was slightly lower.

Losses of crude protein, other than via the effluent, occurred in these experiments; similar losses have been reported elsewhere (Watson 1939). It is difficult to visualize volatile nitrogenous compounds existing in material

of/

of such high acid concentration, yet the fact that 9.35 per cent loss of crude protein took place in the wilted material suggests that losses due to fermentation reactions have occurred.

Discussion

The importance of wilting fresh herbage, prior to ensiling, in order to produce a product of lower moisture content and thereby reduce losses from the silo via the effluent has been stressed by many workers. In the two experiments reported here, although no effluents were produced in the wilted material, the total losses which occurred during ensilage were of a similar order in the wilted as in the fresh grass silages. In spite of this the advantage of wilting, apart from other factors, in eliminating effluent production is important because of the unpleasantness of liquid seeping from a silo and providing an ideal medium for bacterial and fungal growth round the site of the silo.

In this work no studies on the effects of wilting upon the chemical composition of the grass prior to ensiling were carried out, and that marked changes can occur because of the continuance of respiration and enzyme activity has been stressed by Watson (1952). Stone, Reid and Bechdel (1944) working with lucerne, found an increase in fermentable sugar during wilting; this might be an advantage where soluble carbohydrates are low in the original grass herbage. There is also the possibility that carbon assimilation can occur even after the herbage has been cut. Probably the most important factor which is often associated with the ensilage of high/

TABLE 25

Summary of % losses during ensilage process. Expt. No. 5

	Wilted grass silage	*Fresh grass silage
Dry matter	11.45	11.33
Organic matter	13.99	13.66
Crude protein	9.35	10.43
Ether extract	+42.86	+52.31
Crude fibre	7.72	7.21
N.F.E.	21.05	21.12

* Including losses in effluent. Dry matter 2.51%

Nitrogen 4.21%

high dry matter material is the increased possibility of overheating and consequent reduction in protein digestibility. That this did not occur in either of these two experiments (in fact in the second experiment the wilted material showed a higher digestibility value than the non-wilted silage), indicates that wilted grass can be ensiled without any deleterious effects on digestibility. Probably the important reason for this is that the herbage was well consolidated during the filling process. Lactic acid production was high in each case and the wilted silages were as palatable to sheep as the ordinary silages.

Although considerable variation in the results for Nitrogen balance data occurred the values obtained suggest that the wilting process had not adversely affected the protein in the grass as regards its utilization, even if a certain amount of breakdown had occurred as is likely according to McPherson (1952). In experiment 5 the nitrogen balance values suggest that the nitrogenous substances are not being utilized as well in the fresh grass silage as in the wilted grass silage. The theory could be advanced that the animals are making better use of the nitrogen in the wilted silages because of the higher soluble sugar content although the slightly lower intake of dry matter by the animal consuming the ordinary silage (Appendix I Table 59) introduces a further variable factor. It is interesting to note that the quantities of volatile nitrogenous substances in the wilted silages were slightly lower than in the ordinary silages (Appendix I Table 43). Differences in protein digestibility between the two silages in experiment 5 occur, and it might be argued that the fresh grass silage had lost the more easily/

easily digestible nitrogenous substances via the effluent (Appendix I Table 62) which would tend to make the digestibility coefficients lower, but since the total nitrogen loss via this source was almost identical with the nitrogen lost in the effluent in experiment 4, the finding from the latter do not support this argument. It is difficult to explain the large differences in digestibility of the organic residue since the grass-clover herbage was at a similar protein level when cut for each experiment. The main component of this fraction is lignin, and the fact that this constituent is of variable digestibility has been stressed by several workers (Lancaster 1943; Forbes and Garrigus 1950). The constitution of lignin is by no means established and it is possible that it is of variable structure depending upon a number of factors, including plant species and stage of growth; the latter being an expression of the external morphology of the plant in relation to its environment and need not necessarily be closely correlated with lignin deposition in the plant tissue.

The advantages of ensilage over haymaking are well seen from this experiment when the digestibility coefficients in Table 16 are considered. Excluding the ether extract, the constituent which has the most reduced digestibility value in the hay is the N.F.E., presumably due to excessive respiration, fermentation and leaching of the soluble carbohydrates during the drying process.

Summary/

Summary.

The two experiments carried out to compare the nutritive value of wilted grass silage with ordinary grass silage made from similar herbage show little difference in composition and digestibility, although the wilted grass silage had slightly more soluble sugars than the ordinary silage in each case. In the second experiment the results indicate a slight advantage in favour of the wilting process as regards digestibility. The main advantage of wilting grass prior to ensiling is in the absence of effluents and the production of silage of higher dry matter content. It can be seen from these results that well preserved material of high lactic acid content can be obtained by this process. Dry matter losses which occurred during the ensiling process were of a similar order for both wilted and ordinary silages.

(iii) Effects of the addition of molasses on the nutritive value of silages

It has previously been mentioned that any marked reduction of the soluble carbohydrate content of herbage during ensilage, might interfere with the ability of the ruminant to utilize cellulose efficiently. Furthermore the absence in silage of any quantity of soluble sugars might also interfere with the utilization of the nitrogenous substances by the micro-organisms in the rumen. Although the main purpose of these experiments was to study the effects of adding molasses upon the composition and digestibility of silages, an additional experiment, described here, was also carried out in order to compare two different methods of making hay from grass of similar composition to that ensiled.

(a) Silages from spring grass.

Experiment No. 6

The herbage used for silage and hay consisted of a mixture of grasses (predominantly perennial rye-grass) and clovers produced from a seeds mixture sown down under oats at Boghall farm in 1952. The two silos used in this experiment were of the large type (capacity 750 Kg.). The crop was cut on 2nd June, 1954, when the grass heads had fully emerged and the silos were filled on the same day. Molasses, diluted with an approximately equal weight of water, was added to the herbage in one of the silos at the rate of 1.340 Kg./quintal of fresh material. Before replacing the galvanized/

galvanized metal roofs, the tops of the silos were covered with 'sisalkraft' paper and soil to a depth of about 6 ins., in the usual way.

The silo containing the ordinary silage (control) was opened on 16th August, 1954, and its contents weighed, sampled and transferred to metal bins. The other silo was opened on 7th September, when the same procedure was followed. The digestiblity of the fresh grass was determined by the method previously described. On the same day as ensiling, two 508 Kg. lots of fresh grass, of similar composition to that ensiled, were transported to the Bush Estate and made into hay. An area of approximately 1/4 acre of a grass field, previously cut short with an autoscythe, had been set aside for this purpose. One lot of fresh grass was made into hay by the usual farming practice of drying on the ground, with occasional turning, then raking into small heaps then "pikes" until dry enough to be transported indoors. The other system of haymaking was by means of the 'tripod' method, the grass being transferred from the ground to the tripod three days after cutting, when the moisture content had fallen to approximately 50 per cent. Digestibility trials were carried out on these two hays after the silage trials had been completed. Digestibility trials were carried out on the molassed silage, the ordinary silage and the ordinary silage to which molasses was added just prior to feeding. It was therefore necessary to divide the ordinary silage into two equal portions. One of these was fed unchanged, and a quantity of molasses, (diluted with an equal volume of water) approximately equivalent to the soluble carbohydrate loss which had occurred in the unmolassed silo, was added/

TABLE 26

% Composition of fresh grass fed to sheep. Expt. No. 6

Grass	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash
Sample 1	15.70	91.71	12.49	2.47	25.67	51.07	8.30
2	15.56	91.86	12.47	2.30	25.72	51.37	8.14
3	18.56	92.43	11.56	2.28	26.75	51.84	7.57
4	18.40	92.73	11.68	2.28	26.99	51.78	7.27
5	19.40	92.84	10.82	2.38	26.45	53.19	7.16
6	17.70	92.87	11.92	2.03	26.57	52.35	7.13
7	21.42	93.24	10.32	2.19	26.79	53.94	6.76
8	21.25	93.51	10.66	2.15	26.67	54.03	6.49
9	22.15	93.34	9.98	1.75	28.43	53.18	6.66
10	21.90	93.64	9.24	2.11	28.03	54.26	6.36
Mean	19.20	92.82	11.11	2.20	26.81	52.70	7.18

TABLE 27

Analysis of molasses used in experiment 6 and 7

	Dry matter	Ash	Total Nitrogen	Total sugars
Experiment 6	65.3	6.66	0.570	45.70
Experiment 7	70.0	4.71	0.198	53.51

added to the other (i.e. 15.4 g. molasses per Kg. silage) each silage portion offered for feeding being molassed separately.

Both silages were well preserved and indistinguishable as regards odour and general appearance. It can be seen in Table 29 that the pH values (4.05 for the molassed and 4.10 for the ordinary silage) are identical although rather more lactic and acetic acids were produced in the molassed silage than in the control.

The composition of the grass is shown in Table 26. Throughout the 10-day feeding period the crude protein steadily declined while the crude fibre increased, the extreme range throughout this period for these constituents being 3.25 and 2.76 per cent units respectively. The ash content also showed a tendency to decrease steadily throughout this period.

Full details of the digestibility trials are given in Appendix I Tables 63-67, a summary of these results is shown in Table 28. When the hays and silages are compared with the original grass the most outstanding differences are seen in the crude fibre, which is low in the grass, and the N.F.E. fraction which is higher in the grass. The field cured hay is much lower in protein than the other conserved products and digestibility coefficients for this hay are all of a much lower order than for the other materials. The silages are of similar digestibility to the original grass and in the case of crude protein and crude fibre digestibility values are slightly higher for the silages. The addition of molasses to the control silage at the time of feeding has had little effect on the digestibility figures. The advantages of silage making over haymaking as regards nutritive/

TABLE 28

% Composition and digestibility of grass, hays and silages. Expt. No. 6.

	Fresh Grass	Field Cured Hay	Tripod Hay	Control Silage	Control Silage + Molasses	Molassed Silage
			% Composition			
Dry matter	21.3	77.6	78.2	21.3	21.3	21.2
Organic matter	93.21	92.50	90.78	91.44	91.38	91.29
Crude protein	12.79	9.89	12.11	13.63	13.24	12.88
Ether extract	2.20	1.40	1.58	3.15	3.00	3.30
Crude fibre	26.85	36.19	32.41	30.45	29.09	30.35
N.F.E.	51.37	45.02	44.68	44.21	46.05	44.76
Ash	6.79	7.50	9.22	8.56	8.62	8.71
			Digestibility Coefficients			
Dry Matter	73.5) 74.3 75.1)	57.2) 57.4 57.5)	66.6) 66.1 65.5)	74.4) 74.1 73.7)	73.9) 73.7 73.4)	73.5) 74.4 75.3)
Organic matter	75.4) 76.3 77.1)	58.8) 59.1 59.3)	68.1) 67.6 67.0)	76.2) 76.4 76.6)	74.7) 76.2 77.7)	75.6) 76.5 77.3)
Crude protein	61.6) 63.6 65.6)	47.3) 47.3 47.2)	60.5) 59.3 58.0)	68.6) 68.6 68.6)	66.7) 66.6 66.5)	67.2) 68.5 69.7)
Ether extract	44.5) 43.5 42.4)	12.2) 10.9 9.5)	27.5) 27.9 28.2)	59.3) 60.5 61.7)	63.0) 61.9 60.8)	56.4) 57.0 57.5)
Crude fibre	76.3) 76.8 77.3)	69.2) 69.4 69.6)	76.7) 75.9 75.1)	80.4) 81.1 81.7)	76.7) 78.1 79.4)	79.5) 80.1 80.7)
N.F.E.	79.1) 79.9 80.6)	54.5) 54.9 55.3)	65.4) 65.2 64.9)	76.9) 76.8 76.6)	76.5) 76.7 76.9)	76.7) 77.6 78.5)
			Digestible Nutrients			
Dry matter	74.3	57.4	66.1	74.1	73.7	74.4
Organic matter	71.12	54.67	61.37	69.86	69.63	69.82
Crude protein	8.13	4.67	7.18	9.35	8.82	8.82
Ether extract	0.96	0.15	0.44	1.91	1.86	1.88
Crude fibre	20.62	25.12	24.60	24.69	22.72	24.31
N.F.E.	41.04	26.56	29.13	33.96	35.32	34.74
S.E.	62.0	35.4	42.5	60.7	60.0	60.6
T.D.N.	72.0	56.7	61.9	72.3	71.1	72.1

TABLE 29

Organic acid contents of silages. Expt. No. 6.

	pH	Acetic Acid	Butyric Acid	Lactic acid
1. Control silage				
% Fresh	4.10	0.22	Nil	1.80
% Dry matter		1.03	Nil	8.45
2. Molassed silage				
% Fresh	4.05	0.35	Nil	2.20
% Dry matter		1.63		10.38

nutritive value of the final products can be well seen from these figures. Tripoding has definitely improved the value of the hay, when compared with field curing, but that a loss of valuable nutrients occurs can be seen from the digestible nutrient figures. These results are confirmed in the table of losses (Table 31), although the losses for tripod hay are rather high owing to the fact that it was necessary to discard a quantity of mouldy material at the base of the tripod (1/5 of the total). If this material had been included in the calculations, the percentage loss of dry matter for the tripod hay would have been 24.9 per cent. In the case of the field cured hay losses for total and digestible dry matter were 42.84 and 55.84 per cent respectively. The corresponding values for protein were 55.79 and 67.18.

Carbohydrate constituents were determined in the fresh grass and silages and these and their digestibility values are shown in Table 30. It is evident from these results that ensilage of unmolassed grass has resulted in a reduction of the soluble carbohydrate content of the material, whereas the original soluble carbohydrate content in the grass has been approximately maintained in the molassed silage. The soluble sugars present in the silage were again almost completely digestible, the coefficients being 99 and 98.2 for the control and molassed silage respectively. The control silage and molasses experiment also shows a high value (99.2) although the addition of molasses has affected the utilization of fructosan by the animal. It is also interesting to note that this sparing of fructosan fermentation in the rumen, by the addition of molasses, has also

occurred/

TABLE 30

Carbohydrate constituents in fresh grass and silages Expt. No. 6.

	Total sugars	Fructosan	N.H_2SO_4 extract	72% H_2SO_4 extract	Organic residue
1. Fresh grass	5.45	2.68	11.41	24.26	10.87
2. Control silage	4.23	0.47	11.13	22.54	10.84
Faeces					
Sheep T	0.18	0.22	14.79	15.95	20.90
Sheep U	0.16	0.23	15.39	16.25	21.07
Dig. Coefficients					
Sheep T	98.9	87.7	65.0	81.3	50.8
Sheep U	99.0	87.4	64.5	81.5	50.1
Mean	99.0	87.6	64.8	81.4	50.5
Dig. Nutrients					
Mean	4.19	4.12	7.21	18.35	5.47
3. Control silage + molasses	8.24	0.41	10.45	21.17	10.18
Faeces					
Sheep R	0.25	0.53	15.43	17.87	18.94
Sheep S	0.26	0.47	14.64	15.69	19.18
Dig. Coefficients					
Sheep R	99.2	67.7	60.3	77.3	50.0
Sheep S	99.2	71.4	62.4	80.1	49.4
Mean	99.2	69.6	61.4	78.7	49.7
Dig. Nutrients					
Mean	8.17	2.85	6.42	16.66	2.72
4. Molassed silage	4.15	3.68	11.61	22.36	10.69
Faeces					
Sheep R	0.31	0.25	15.56	15.48	20.30
Sheep S	0.28	0.28	13.92	14.21	20.18
Dig. Coefficients					
Sheep R	98.0	98.2	64.6	81.7	49.8
Sheep S	98.3	98.1	70.4	84.3	53.3
Mean	98.2	98.2	67.5	83.0	51.6
Dig. Nutrients					
Mean	4.08	3.61	7.84	18.56	5.52

TABLE 31

% Losses incurred during hay and silage making. Expt. No. 6.

	Tripod Hay		Field cured Hay		Ordinary Silage		*Molassed Silage	
	Total	Digestible	Total	Digestible	Total	Digestible	Total	Digestible
Dry matter	40.55	47.12	42.84	55.84	1.11	1.33	2.89	1.23
Organic matter	42.11	44.71	43.29	52.66	1.09	3.30	4.76	0.73
Crude protein	43.71	47.55	55.79	67.18	+ 5.21	+ 7.13	0.36	+ 9.63
Ether extract	57.42	72.53	63.64	91.21	+41.51	+91.66	+47.52	+96.90
Crude fibre	28.26	29.05	22.94	30.38	+12.15	+ 8.93	+14.27	+19.22
N.F.E.	48.30	57.85	29.46	62.99	14.83	18.12	17.26	14.22
Soluble sugars	-	-	-	-	23.29	-	49.51	-
Fructosan	-	-	-	-	82.55	-	+38.99	-
N.H_2SO_4 ext.	-	-	-	-	3.51	-	+ 2.81	-
72% H_2SO_4 ext.	-	-	-	-	8.11	-	6.82	-
Organic residue	-	-	-	-	1.10	-	0.62	-

* Including total losses in effluent. Dry matter 0.73% Nitrogen 0.40% Organic matter 0.67%.

occurred in the silo where molasses was added to the original grass. The digestibility coefficients for the organic residues of all three silages are relatively high viz. 50.5; 49.7 and 51.6 for the control, control + molasses and molassed grass silages respectively.

The total losses incurred during ensilage are summarized in Table 31. It can be seen that, with the exception of the carbohydrate constituents these losses are of a low order; the % dry matter losses from the control and molassed silage being only 1.11 and 2.89 respectively. A breakdown of the 72% H_2SO_4 extract has occurred in both silages, since the main component in this fraction is cellulose, these results indicate that this constituent might be broken down during ensilage. This result is not verified by the crude fibre, although this fraction is itself of heterogeneous composition and does not necessarily contain all the cellulosic material. The almost complete recovery of the 'organic residue' in the silage is indicative of the stability of this component to bacterial breakdown, a result which makes even more complex the significance of its disappearance during ruminant digestion.

The results of the nitrogen balance experiments are given in Table 32. All animals used in these trials were of similar age, weight and breed. The lowest retention of nitrogen occurred in the two sheep consuming field cured hay, although the different results obtained for these animals would seem to indicate that if more hay had been consumed by sheep R, then higher retention values would have been obtained. Unfortunately because of the poor digestibility of this hay, the intake of digestible nitrogen was lower than/

TABLE 32

Nitrogen balance. Expt. No. 6.

	Urine			Food	Faeces	Balance	% Dig. N
	Volume (ml.)	% N.	Wt. N (g)	Wt. of N (g)	Wt. of N (g)	of N	retained
1. Fresh grass							
Sheep S. 1.	8,500	.357	30.35				
2.	7,900	.251	19.83				
Total	16,400		50.18	165.4	63.5	51.8	50.8
Sheep T. 1.	8,790	.351	30.85				
2.	9,060	.245	22.20				
Total	17,850		53.05	166.9	53.4	56.5	52.4
2. Control silage + molasses							
Sheep R. 1.	7,660	.488	37.38				
2.	9,170	.571	52.36				
Total	16,830		89.74	221.9	74.0	58.2	39.3
Sheep S. 1.	9,640	.430	41.45				
2.	8,310	.529	43.96				
Total	17,950		85.41	224.5	75.1	64.0	42.8
3. Control silage							
Sheep T. 1.	9,335	.609	58.85				
2.	10,650	.492	52.40				
Total	19,985		111.25	219.2	68.8	39.1	26.0
Sheep U. 1.	10,140	.534	54.15				
2.	10,280	.602	61.89				
Total	20,420		116.04	213.7	67.2	30.5	20.8
4. Molassed silage							
Sheep R. 1.	10,627	.439	46.65				
2.	12,165	.462	56.20				
Total	22,792		102.85	285.6	85.0	60.8	35.0
Sheep S. 1.	13,495	.498	67.21				
2.	12,933	.458	59.23				
Total	26,428		126.44	258.6	78.3	43.8	24.3

5./

TABLE 32

Nitrogen balance. Expt. No. 6 (Continued)

		Urine			Food	Faeces	Balance	% Dig. N
	Volume (ml.)	% N.	Wt. N (g)	Wt. of N (g)	Wt. of N (g)	of N	retained
5. Field cured hay								
Sheep R. 1.	2,700	1.453	39.23				
2.	3,000	1.170	35.11				
Total	5,700		74.34	171.8	90.6	6.9	8.50
Sheep S. 1.	2,575	1.313	33.73				
2.	2,225	1.683	37.44				
Total	4,800		71.17	184.2	97.3	15.7	18.06
6. Tripod hay								
Sheep T. 1.	7,050	.629	44.31				
2.	6,150	.783	48.13				
Total	13,200		92.44	227.3	89.7	45.2	32.85
Sheep U. 1.	8,160	.593	48.35				
2.	6,450	.680	43.89				
Total	14,610		92.24	227.3	95.4	39.7	30.10

than in the tripod hay experiment, which makes a direct comparison of the results in the final columns difficult to interpret. The highest balance of nitrogen figures (per cent of digestible nitrogen retained) are those of the fresh grass experiment viz. 50.8 and 52.4 for sheep S and T respectively. The intakes of digestible nitrogen by the two sheep consuming tripod hay are slightly higher than those on the fresh grass experiment, yet the utilization of digestible nitrogen is much lower viz. 32.85 and 30.10 for sheep T and U respectively.

In the control silage and control silage + molasses experiments the results are comparable since the intakes of digestible nitrogen (g.) are similar viz. 150.4 (Sheep T) and 146.5 (sheep U) for the control experiment and 147.9 (sheep R) and 149.4 (sheep S) for the control + molasses trial. It can be seen that utilization of digestible nitrogen in the silage where molasses has been added, is much greater than in ordinary silage fed above.

One other rather interesting feature of these results can be seen in the urine figures. The volume of urine excreted by the sheep consuming the field cured hay is only about one-third of the volumes excreted by the animals on the tripod hay diet; these differences are also reflected in the percentage composition figures.

(b) Silage from autumn grass.

Experiment No. 7.

Experiment No. 6 was repeated using autumn grass instead of spring grass. In this experiment, however, the conservation process was restricted to/

to silage making only.

The same field was used as a source of fresh herbage as in the previous experiment and grass was cut at a similar stage of growth on September 10th 1954. The silos were also filled on 10th September and as in the previous experiment molasses was added to one silo at the rate of 1.340 Kg./quintal of fresh herbage. The silo containing molassed silage was opened on 28th March, 1955 and the ordinary silo on 27th April, 1955. The digestibility of fresh grass, cut daily, was also determined. The composition of fresh grass cut over the 10-day feeding period is shown in Table 33, the protein and fibre results show more erratic day-to-day variation than in the previous experiment with the lowest protein and highest fibre figures occurring on the 5th day.

As in the previous experiment the ordinary silage was divided into two equal portions. One of these was fed unchanged and to the other was added a quantity of molasses approximately equivalent to the soluble carbohydrate loss which had occurred in the unmolassed silo. In the previous experiment the soluble sugar content of the spring grass was 5.45 per cent and the fructosan 2.68 per cent making a total of 8.13 per cent soluble carbohydrates. In the autumn grass the corresponding figures for soluble sugars and fructosan were 2.02 and 10.60 making a total of 12.62.

The sugar and fructosan percentages in the control silages made from spring grass were 4.23 and 0.47 respectively whereas in the control silage made from the autumn grass the values were 0.45 and 0.38. In view of the larger/

TABLE 33

Composition of autumn grass fed to sheep. Expt. No. 7

	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash
Sample 1	16.6	90.31	13.93	4.29	26.32	45.77	9.69
2	18.6	88.21	12.82	4.13	25.97	45.29	11.79
3	17.7	89.21	13.25	4.14	27.55	44.27	10.79
4	17.5	90.34	12.20	4.15	28.07	45.92	9.66
5	15.0	90.89	11.82	3.80	28.46	46.85	9.11
6	16.8	90.06	13.47	3.97	27.51	45.11	9.94
7	16.3	89.45	12.93	3.96	27.12	45.44	10.55
8	16.7	89.33	12.81	3.94	26.32	46.26	10.67
9	18.9	89.75	12.33	3.78	26.65	46.17	10.25
10	18.0	89.51	12.10	3.72	27.47	46.22	10.49
Mean	17.2	89.71	12.77	3.99	27.14	45.81	10.29

TABLE 34

% Composition and digestibility of autumn grass and silages. Expt. No. 7.

	Fresh Grass	Control Silage	Control silage + molasses	Molassed silage
			% Composition	
Dry matter	15.89	17.57	19.10	17.10
Organic matter	90.94	88.95	89.59	89.04
Crude protein	15.25	15.81	13.75	15.97
Ether extract	3.81	4.50	3.83	4.68
Crude fibre	26.95	26.26	22.38	27.47
N.F.E.	44.93	42.38	59.63	40.92
			Digestibility Coefficients	
Dry matter	71.4, 71.6 → 71.5	74.3, 67.9 → 71.1	72.9, 72.8 → 72.9	71.3, 72.1 → 71.7
Organic matter	74.4, 74.7 → 74.6	77.6, 71.7 → 74.7	75.3, 75.4 → 75.4	75.0, 75.4 → 75.2
Crude protein	67.1, 68.6 → 67.9	78.0, 71.7 → 74.9	68.8, 67.8 → 68.3	74.4, 74.4 → 74.4
Ether extract	66.6, 63.0 → 64.8	63.2, 56.7 → 60.0	60.1, 60.3 → 60.2	63.5, 64.7 → 64.1
Crude fibre	72.2, 73.9 → 73.1	81.5, 76.0 → 78.8	76.4, 76.2 → 76.3	81.0, 80.7 → 80.9
N.F.E.	78.3, 77.9 → 78.1	76.5, 70.7 → 73.6	81.5, 81.9 → 81.7	72.5, 73.5 → 73.0
			Digestible Nutrients	
Dry matter	71.5	71.1	72.9	71.7
Organic matter	67.84	67.44	67.55	66.96
Crude protein	10.35	11.84	9.39	11.88
Ether extract	2.47	2.70	2.31	3.00
Crude fibre	19.70	20.69	17.08	22.22
N.F.E.	35.09	31.19	48.72	29.87
S.E.	61.4	61.0	74.1	61.0
T.D.N.	70.7	69.8	80.4	70.7

TABLE 35

Organic acid contents of silages. Expt. No. 7.

	pH	Acetic acid	Butyric Acid	Lactic acid
1. Control silage				
% Fresh	4.32	0.58	Nil	1.36
% Dry matter		3.30	Nil	7.74
2. Molassed silage				
% Fresh	4.30	0.55	Nil	1.67
% Dry matter		3.22	Nil	9.77

larger loss of soluble carbohydrates resulting in the ensilage of the autumn grass it was necessary to add considerably more molasses viz. 43 g. molasses per Kilogram fresh silage in experiment 7 than previously. It can be seen from Table 34 that the composition of the silage - molasses mixture differs considerably from the control and molassed silages. Whereas these last two products do not differ widely in composition from the original autumn grass, the silage-molasses mixture has much lower protein and fibre values and a higher N.F.E. value than the other two silages.

As in the previous experiment the digestibility of the control and molassed silages is similar to the original grass, there being slightly higher values for crude protein and crude fibre fractions in the silages. The addition of sugars to the control silage has caused the digestibility coefficient of the N.F.E. fraction to be increased, but has not significantly affected the other constituents reported in Table 34, except possibly a slight lowering of the crude protein digestibility. The high digestibility of the sugars in the molasses is verified in Table 36 where mean coefficients for the control, control + molasses and molassed silage are 88.8, 99.6 and 92.2 respectively. It can be seen from this table that the addition of molasses at the time of feeding has again affected the digestibility of the fructosan, although in view of the small quantity originally present (0.38%) it is doubtful if much significance could be attached to this result. As in the previous experiment the sugars in the 72 per cent extract show higher digestibility values than those in the N acid extract. The organic residue/

residue is also digestible to a relatively high degree.

The pH values and organic acid contents of the control and molassed silages are shown in Table 35; both silages were well preserved, yet in spite of the similarity in pH values, the molassed silage contained more lactic acid than the control silage. The acetic acid values are similar and butyric acid was absent in both products.

As in the previous experiment, the S.E. values of the control and molassed silage, which in this case are both 61.0, are similar to the S.E. of the original grass viz. 61.4 and it can again be concluded that the nutritive value of the grass, as measured by digestibility data, has not decreased as a result of the ensilage process. The nitrogen balance data, however, shown in Table 37 indicate that the utilization of the nitrogen in the autumn grass is very low indeed. When this table is compared with table 32 of experiment 6, it can be seen that the sheep on the autumn grass diet excreted almost twice the volume of urine as the animals consuming the spring grass and as the percentage of nitrogen in the urine from the sheep in experiment 7 is higher than in experiment 6 the result is that more than twice the amount of nitrogen has been excreted in the autumn grass diet. This finding is discussed in a later section. As in the previous trial the addition of molasses to the silage at the time of feeding has considerably improved the retention of nitrogen by the animal.

The percentage losses which occurred during ensilage are given in Table 38; it can be seen that considerable differences occur between the two treatments. In this experiment addition of molasses to the grass has/

TABLE 37

Nitrogen balance. Expt. No. 7.

	Urine			Food	Faeces	Balance	% Dig. N
	Volume (ml.)	% N.	Wt. N (g)	Wt. of N (g)	Wt. of N (g)	of N	retained
1. Fresh grass							
Sheep T. 1.	15,940	0.358	57.07				
2.	13,610	0.381	51.85				
Total	29,550		108.92	175.96	57.87	9.17	7.77
Sheep U. 1.	15,010	0.398	59.74				
2.	12,595	0.418	52.65				
Total	27,605		112.39	175.96	55.29	8.28	6.86
2. Control silage + molasses							
Sheep R. 1.	16,260	0.323	52.59				
2.	15,075	0.334	50.34				
Total	31,335		102.93	285.7	89.2	93.6	47.60
Sheep S. 1.	15,630	0.379	59.19				
2.	15,600	0.377	58.75				
Total	31,230		117.94	285.7	92.0	75.8	39.10
3. Control silage							
Sheep T. 1.	15,275	0.452	69.07				
2.	17,215	0.393	67.92				
Total	32,490		136.79	248.4	54.7	56.9	29.38
Sheep U. 1.	16,240	0.415	67.41				
2.	19,050	0.332	63.21				
Total	35,290		130.62	248.4	70.2	47.6	26.71
4. Molassed silage							
Sheep T. 1.	17,200	0.394	67.79				
2.	14,300	0.463	66.27				
Total	31,500		134.06	246.7	63.3	49.34	26.90
Sheep U. 1.	13,330	0.412	54.87				
2.	16,600	0.385	63.91				
Total	29,930		118.78	248.8	63.7	66.32	35.80

TABLE 38

% Losses incurred during silage making

	*Ordinary silage		*Molassed silage	
	Total	Digestible	Total	Digestible
Dry matter	16.11	16.59	9.98	9.74
Organic matter		17.85	11.81	11.13
Crude protein	14.46	3.96	3.47	- 3.32
Ether extract	0.81	8.30	- 1.67	- 9.44
Crude fibre	18.24	11.86	3.02	- 1.53
N.F.E.	20.87	25.45	21.80	23.36
Soluble sugars	81.22	-	82.29	-
Fructosan	97.00	-	95.33	-
N. H_2SO_4 ext.	12.88	-	0.61	-
72% H_2SO_4 ext.	26.66	-	16.38	-
Organic residue	4.34	-	- 4.60	-

* Including losses in effluent. Dry matter 3.48% Nitrogen 0.66 Org matter 2.61% Sugars 1.52% .

* Including losses in effluent. Dry matter 5.63% Nitrogen 1.57% Dry matter 4.41% Sugars 0.57%.

has effected considerable saving in the breakdown of all constituents. In the ordinary silage the loss in crude fibre (11.86%) is relatively high, this high loss of polysaccharide material is also reflected in the carbohydrate analysis, the greatest loss occurring in the 72% acid extract material. In view of the high loss of this constituent the possibility of considerable cellulose breakdown having occurred cannot be overlooked. This loss of carbohydrate material, other than soluble sugars and fructosan, which can occur during the ensilage process may be an important factor in the explanation of the large losses which have been reported in the literature (Dodsworth 1954; Sears and Goodall 1947). The % losses via the effluent (Appendix I Table 77) are also summarized in Table 38 and it can be seen that again the losses from this source are of a low order.

Discussion

Because of the importance to the ruminant animal of a supply of easily fermentable substances in order to provide a readily available source of energy to the micro-organisms in the rumen, it is important to consider what effect the reduction in soluble carbohydrate content in grass has upon the nutritive value of the resultant silages. There are at least two possible changes, brought about by silage fermentation, which could interfere with ruminant digestion and which might deleteriously effect the value of the food to the animal. These are firstly the effect on cellulose breakdown and secondly the effect on nitrogen utilization. In the first instance the results in this work show that addition of soluble sugars in the form of

molasses/

molasses has had little effect on the digestibility of the fibre fraction; in each experiment the fibre is digested to a slightly lower degree where molasses has been added at the time of feeding. Similar differences are found in the 72 per cent acid extract although it is doubtful if these differences are significant. When this is considered, however, along with the fact that the digestibility of the fibre in all silages is higher than in the original grasses, it can be concluded that the ensiling process does not deleteriously effect the digestibility of the fibre fraction. However there is a factor which may be important and which is not measured during digestibility experiments; this is the rate at which cellulose digestion occurs. Since Hoflund, Quin and Clark (1948) have shown that a balance between available carbohydrate and protein is important, it cannot be concluded that the reduction in soluble sugars during ensilage has not necessarily affected the rate of cellulose digestion in spite of the negligible differences in digestibility coefficients of the crude fibre fraction.

In the case of nitrogen utilization, a considerable variation occurs, although the values for both spring and autumn grass silage suggest that better utilization of the nitrogenous constituents may be obtained when a source of readily fermentable carbohydrate is made available. The rumen microflora is so complex an association, however, that relatively little is known with certainty about the more important microbial inter-relationships within it. Whilst a study of the microbiological reactions occurring in the rumen is outside the scope of this thesis, it is obvious

that/

that a major factor in a study of ruminant nutrition is the reactions brought about by the bacteriological and protozoological populations in the rumen. Johns (1951) and Sijpesteijn and Elsden (1952) have shown, that the mixed rumen microflora is able to convert succinic to propionic acid by decarboxylation with great speed and is also able slowly to ferment lactic acid. This latter finding is important in that the main product of silage fermentation may be used by certain rumen micro-organisms as a source of energy. Oxford (1955) has also stated that Veillonella gazogenes is remarkable in that it will not ferment carbohydrates, but only lactic, succinic and certain related C_4 acids. It is impossible to be specific about the individual chemical reactions that occur in the rumen. Obviously it would be an advantage to be able to distinguish between the bacteria which can convert non-protein nitrogen into cell protein, from those which attack amino-acids and proteins to yield ammonia even in the presence of carbohydrate.

The fact that the losses occurring during ensilage of spring grass are of a very low order suggest that where conditions are ideal it is possible to convert grass into silage without excessive external loss from the silo of fermentative products. The extent to which losses occur during ensilage is dependant upon a number of factors, the exact nature of which is not fully understood. The fact that spring and autumn grass cut at a similar protein content, ensiled in the same silos, consolidated, weighted and roofed in an identical manner has resulted in negligible losses from the spring herbage yet dry matter losses of over 16 per cent from the autumn cut material/

material is difficult to explain. It is obvious that further research is required to explain the large variation here and even greater differences reported in the literature. That the presence of fermentable carbohydrates, adequate consolidation, correct temperature and presence of lactobacilli are important factors have been proved, but that there are other agents which play a part in the ensilage process cannot be overlooked. The relatively high losses of crude fibre in the autumn grass experiment suggest that this constituent may be broken down although the apparent gains in this fraction in the spring grass experiment suggest that the method of fibre determination may produce faulty results in that 'crude fibre' in the grass may not be of similar constitution to that in the silage. The advantages of the ensilage system over haymaking are again demonstrated in these experiments although it is obvious that losses can be reduced considerably where quick drying, as in the tripod method, is practised.

Summary.

Two experiments are described in which silage was made from both spring and autumn grass with and without the addition of molasses. The latter added to the grass at the time of ensiling did not markedly effect the type of preservation which occurred except to cause a slight increase in lactic acid production.

In addition to the usual analysis, carbohydrates were determined in both feed and faeces. A considerable difference in soluble carbohydrate content/

content occurred between the spring grass and autumn grass and in the silages made from these materials. The total sugar and fructosan constituents were almost completely digested in both the fresh grass and silage experiments. The least digestible fraction was the 'acid insoluble organic residue'.

The addition of molasses to the ordinary silages did not significantly affect the digestibilities of the various constituents although there was an apparent increase in utilization of total digestible nitrogen when additional sugars were made available.

The losses occurring during ensilage of the spring grass are of a very low order whilst those obtained in the silages made from autumn grass show losses of a greater magnitude with the unmolassed material producing the highest losses.

In addition to the silages hay was also made from the spring grass by two different methods viz. ordinary field curing and the tripod method. The latter system was the more successful in conserving nutrients and producing material of higher digestibility although neither of these methods compared in efficiency with the ensilage process.

(iv) Comparison of the nutritive values of Spring and Autumn grass

In experiments 6 and 7 digestibility trials and nitrogen balance experiments were carried out on fresh grass cut from the same field in late spring (June) and in autumn (September) and because of the generally accepted view that autumn grass had not the same productive value as spring grass, it is of some importance to compare the results of these two experiments.

It can be seen from Tables 26 and 33 that the grasses were cut at a similar stage of maturity - the spring grass having mean protein and fibre contents respectively of 11.11 and 26.81, while the corresponding figures for the autumn grass were 12.77 and 27.14 respectively. When the digestibility coefficients of these two grasses are compared, with the exception of the ether extract which is of little significance because of its low value, there is little difference between them; the protein in the autumn grass being of slightly higher digestibility (67.9) than that of the spring grass (63.6). The S.E. values calculated from the mean composition figures in tables 26 and 33 are 62 for the spring grass and 61 for the autumn grass. It would appear therefore that any differences which exist between spring and autumn grass are not manifested in the crude analysis or digestibility results.

Several attempts have been made to explain the difference in nutritive value between spring and autumn grass. Moris, Wright and Fowler (1956) attribute/

atributed small differences in milk yield that occurred in their experiments to a difference in the biological value of the protein in the grass produced in spring and in autumn and in particular to a difference in lysine content. On the other hand, the chemical studies of Chibnall (1939) and his colleagues suggest that the amino acid content of herbage is remarkably constant. This fact was also observed by Waite, Fenson, and Lovett (1953) in studying the content of basic amino-acids in different grasses at different stages of growth throughout the season. In this work one interesting difference which might be of some significance is seen in the sugar and fructosan values for the samples of grass ensiled; unfortunately carbohydrate analyses were not carried out daily on the samples of grass fed to the sheep and no indication as to the extent of variation of the soluble carbohydrate fraction was obtained. However the fact that the sugar content of the spring grass sample (5.45%) was higher than that of the autumn grass sample (2.02%) and the fructosan in the spring grass (2.68%) markedly lower than that in the autumn grass (10.60%) might be of some significance. This increase in fructosan content of grass does not agree with the work of Waite and Boyd (1953) although Wylam (1955) has shown with ryegrass, that a seasonal increase in fructosan can occur. This difference in carbohydrate content which may account for the spring-autumn variation in nutritive value has also been noted by Sjollema (1950) and Waite and Boyd (1953). Holmes (1956) has recently studied this question of spring v. autumn grass with regard to milk production and has reported increased milk yields of 3 - 5 per cent with cows on spring grass compared with/

with autumn grass; on statistical analysis, however, these differences were not significant. Holmes has suggested that increased yields on spring grazing may be due to an increase in herbage consumption.

When the nitrogen balance data are compared (Tables 32 and 37), the differences here are striking. The percentages of digestible nitrogen retained by the two sheep consuming the spring grass are 50.8 and 52.4, while the two animals on the autumn grass experiment only retained 7.77 and 6.86. It would appear from these results that the nitrogenous constituents in the autumn grass are not being well utilized. Before accepting this conclusion it is necessary to consider the metabolism of nitrogen utilization by the animal since a large excretion of nitrogen in the urine may not necessarily indicate poor protein utilization if the animal does not require all the digestible protein for production purposes provided by the ration.

It is generally agreed that where nitrogen balance trials are carried out with sheep it is essential for animals to be growing, i.e. have a definite need for nitrogenous substances to build up body protein for production purposes and secondly it is necessary for the ration to provide sufficient energy in order to avoid protein breakdown as an energy source. The S.E. value of the autumn grass is 61; according to Watson (1949) the S.E. requirement of a 100 lb. growing sheep for maintenance is 7.5 lb. per week. The liveweights of the two sheep T. and U. at the commencement of the autumn grass experiment were 100 lb. and 90 lb. respectively and although the daily intakes of dry matter were of a low order viz. 861.5 g. (equivalent/

(equivalent to 1.9 lb) this quantity of herbage was sufficient to supply 8.25 lb. S.E. per week to each animal, which is in excess of the maintenance requirement. Furthermore the fact that these animals were confined to crates in which movement was at a minimum, would tend to reduce their maintenance requirement below the values normally quoted for animals of this size.

Another important factor which should be taken into account, is the possible seasonal variation in the animals protein requirement for the growth of wool. A further variable factor in these experiments is the age of the animal, since the autumn grass trial was carried out some 4 months after the spring grass experiment. It was with the object of attempting to determine what effect these various factors have upon nitrogen utilization that the following experiment were carried out.

(v) Effect of season and age of sheep on the digestibility and utilization of nitrogen in grass.

Experiment 8.

Ideally a study of these factors involves the feeding of similar fresh herbage to sheep of varying ages at different times of the year. The best way of doing this is by the deep freeze method; unfortunately equipment for this was unavailable and it was therefore decided to feed a standard dried grass cube. Two separate series of trials were carried out in July and November on the same sheep. In July two half-bred wether animals (A and B) 14 months of age and two sheep of the same breed (T. and U) 27 months old were fed the dried grass pellets (details of the experiment are given in Appendix I Table 78). The pellets were stored during the summer in paper bags in a dry and cool atmosphere and were fed to the same sheep in late autumn (November). In addition, two young Cheviot lambs (F and G) 9 months of age were also fed the pellets in autumn.

The digestibility results are summarized in Table 39. The digestibility coefficients of the dry matter are remarkably constant, the values for the two young lambs F and G being slightly lower than for the older animals; this difference, however, only amounts to 2.9 per cent of the mean values for $2\frac{1}{2}$ year sheep T and U, and is therefore of little significance. As Raymond (1954) has pointed out, it is generally assumed in feeding studies that the digestive ability of a ruminant remains relatively constant after it is weaned, and yet there is little experimental evidence/

TABLE 39

Digestibility Coefficients of constituents in dried grass. Expt. 8.

	July				November					
	A	B	T	U	A	B	T	U	F	G
Dry matter	51.4	51.9	52.7	52.6	52.8	52.5	50.0	51.9	49.6	49.
Organic matter	52.1	52.7	53.8	53.4	53.6	53.3	51.1	52.8	50.1	49.
Crude protein	61.8	61.6	64.0	64.0	63.3	64.9	62.0	63.9	60.7	62.
Ether extract	48.0	48.4	47.6	48.2	41.9	47.4	35.3	37.4	34.4	34.
Crude fibre	34.0	36.7	40.3	39.0	40.0	39.7	36.0	40.4	36.7	33.
N.F.E.	61.5	60.9	60.2	60.1	60.4	59.5	58.8	58.6	56.6	56.

TABLE 39 a.

Age of sheep (in months). Expt. 8.

July				November					
A	B	T	U	A	B	T	U	F	G
14	14	27	27	18½	18½	31½	31½	9	9

TABLE 39 b.

Composition of dried grass pellets (on d.m. basis). Expt. 8.

Org. Matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash
92.85	14.24	1.56	31.82	45.23	7.15

TABLE 40

Nitrogen balance. Expt. No. 8.

	Total Volume (ml.)	% N.	Wt. of N (g)	Food Wt. N (g)	Faeces Wt. N (g)	Balance of N (g)	% Dig. retain
July.							
Sheep A. 1.	9,630	0.666	64.17				
2.	10,895	0.578	63.00				
Total	20,525		127.17	255.25	97.60	30.48	19.33
B. 1.	4,790	1.309	62.70				
2.	4,015	1.574	63.19				
Total	8,805		125.89	255.25	97.90	31.44	19.98
T. 1.	4,970	1.771	88.02				
2.	4,505	1.866	84.07				
Total	9,475		172.09	340.29	122.40	45.80	21.02
U. 1.	6,530	1.147	74.87				
2.	5,240	1.537	80.55				
Total	11,770		155.42	297.65	107.00	35.23	18.4
						Mean	19.70
November.							
Sheep A. 1.	8,350	0.951	79.44				
2.	8,563	0.900	77.08				
Total	16,913		156.52	318.29	116.98	44.79	22.25
B. 1.	4,349	1.911	83.12				
2.	4,394	1.988	87.35				
Total	8,743		170.47	321.02	112.80	37.75	18.13
T. 1.	5,444	1.875	102.13				
2.	5,997	1.917	114.94				
Total	11,441		217.07	441.10	167.74	56.29	20.59
U. 1.	6,599	1.615	106.57				
2.	4,879	1.952	95.25				
Total	11,478		201.82	398.72	143.78	53.12	20.84
						Mean	20.49
F. 1.	3,012	1.940	58.42				
2.	2,888	2.041	58.95				
Total	5,900		117.37	247.44	97.26	32.81	21.89
G. 1.	3,960	1.621	64.18				
2.	3,556	1.753	62.33				
Total	7,516		126.51	247.44	93.20	27.73	17.9

evidence for this assumption, apart from the data given by Wolff (1873), which indicated that lambs had the same digestive ability at 6 and 14 months. Raymond himself showed that there was a tendency for digestive ability to increase with age and regression analysis on the data obtained showed an average increase of about 1 unit of digestibility from lambs to 2 year olds. It can be seen from Table 39 that a similar tendency occurred in the July experiment although in autumn, the older animals did not digest the dry matter of the pellets to the same extent as the 1½ year old sheep. A more striking difference is seen in the fibre digestibilities and here there does seem to be a definite trend of increasing digestibility with age, although the poor duplication of sheep T and U shown on the autumn diet would tend to interfere with any significant proof from statistical analysis.

The nitrogen balance data (Table 40) are interesting in that the percentage of digestible nitrogen retained by all animals on both spring and autumn ration is remarkably constant, the mean values for sheep A, B, T and U on the spring and autumn diets being 19.70 and 20.45 respectively. From this it would appear that neither age nor season has little effect on nitrogen utilization. This finding is important in supporting the view that some factor in the food itself is responsible for the variation in spring and autumn grass, and the results as a whole suggest that the nitrogenous substances in autumn grass have not the same 'biological value' to the animal as the nitrogenous constituents in the spring grass.

TABLE

Summary of Composition and Nutritive Value of Silages.

Ref. No.	Expt.	Sample	In Fresh Material					% Composition of dry matter				Digestibility Coefficients					Digestible Nutrients in dry matter						
			D.M. %	pH	Acetic Acid %	Butyric Acid %	Lactic Acid %	O.M.	C.P.	E.E.	C.F.	N.F.E.	Ash	N.A.F.	L.D.N.	O.M.	C.P.	E.E.	C.F.	N.F.E.	O.M.	C.P.	E.E.	C.F.	N.F.E.	S.E.	T.D.N.
1	1	Farm silage from top of silo	15.31	3.90	0.39	0.01	0.30	91.41	11.52	2.97	34.51	42.41	8.59	44.90	54.8	67.5	48.3	69.7	76.5	65.2	61.62	5.56	2.07	26.38	27.62	53.2	64.2
2	1	Farm silage from bottom of silo	19.19	5.25	0.16	0.87	0.05	89.97	18.00	3.98	35.69	32.30	10.03	47.26	49.6	63.5	71.1	66.1	70.3	51.4	57.13	12.80	2.63	25.10	16.60	45.9	60.4
3	2	'Good' silage	21.15	4.40	0.19	Nil	-	91.37	23.21	6.65	28.40	33.11	8.63	36.61	57.3	81.4	81.1	69.4	87.9	78.6	74.38	18.82	4.62	24.96	26.02	69.2	80.2
4	2	'Bad' silage	13.46	4.90	0.26	Nil	-	89.46	23.06	5.55	28.95	31.90	10.54	40.80	55.2	80.3	80.7	65.7	87.8	75.7	71.84	18.61	3.65	25.42	24.15	65.7	76.5
5	3	'Good' silage	15.17	4.00	0.34	Nil	1.65	85.67	17.96	2.60	21.33	43.78	14.33	32.73	60.2	78.4	74.3	41.9	84.2	79.4	67.17	13.34	1.09	17.96	34.76	61.1	68.5
6	3	'Bad' silage	15.71	4.60	0.48	0.02	1.28	85.97	17.76	2.30	22.80	43.11	14.89	32.74	60.0	80.3	76.6	48.0	86.0	80.6	69.03	13.60	1.10	19.61	34.75	62.6	70.4
7	4	Wilted grass silage	23.98	4.20	0.17	0.07	1.28	90.77	15.57	3.67	27.37	44.16	9.23	38.48	58.6	77.5	76.3	71.0	79.5	77.3	70.34	11.88	2.61	21.76	34.14	62.7	73.6
8	4	Fresh grass silage	17.65	3.70	0.59	Nil	1.39	90.90	14.07	2.54	28.31	45.98	9.10	38.59	50.8	78.0	76.0	61.8	80.1	78.3	70.90	10.69	1.57	22.68	36.00	62.1	72.9
9	5	Wilted grass silage	23.71	4.00	0.83	Nil	2.41	88.26	12.15	3.23	29.31	43.57	11.74	39.50	57.5	80.3	67.2	78.2	87.0	79.5	70.87	8.16	2.53	25.50	34.64	62.6	74.0
10	5	Fresh grass silage	18.72	3.90	0.80	Nil	1.88	88.09	11.99	3.44	29.93	42.73	11.91	38.98	55.2	75.5	58.6	74.5	82.6	75.4	66.51	7.03	2.56	24.72	32.22	58.2	69.7
11	6	Ordinary silage	21.30	4.10	0.22	Nil	1.80	91.44	13.63	3.15	30.45	44.21	8.56	39.57	59.3	76.4	68.6	60.5	81.1	76.8	69.86	9.35	1.91	24.69	33.96	60.7	72.3
12	6	Molassed silage	21.20	4.05	0.35	Nil	2.20	91.29	12.88	3.30	30.35	44.76	8.71	39.92	60.7	76.5	68.5	57.0	80.1	77.6	69.82	8.82	1.88	24.31	34.74	60.6	72.1
13	7	Ordinary silage	17.57	4.32	0.58	Nil	1.36	88.95	15.81	4.50	26.26	42.38	11.05	39.00	53.7	74.7	74.9	60.0	78.8	73.6	66.44	11.84	2.70	20.69	31.19	61.0	69.8
14	7	Molassed silage	17.10	4.30	0.55	Nil	1.67	89.04	15.97	4.68	27.47	40.92	10.96	39.93	55.4	75.2	74.4	64.1	80.9	73.0	66.96	11.88	3.00	22.22	29.87	61.0	70.7
15	9	Ordinary silage	18.95	3.99	-	-	-	90.05	14.89	5.17	28.73	41.27	9.95	38.25	58.4	77.3	72.0	73.0	80.0	77.5	69.61	10.72	3.77	22.98	31.98	63.8	74.1
16	9	Ordinary silage, inoculated.	19.60	3.63	-	-	-	89.89	14.74	4.38	29.20	41.57	10.11	38.16	58.4	79.0	72.2	68.0	83.4	80.9	71.01	10.64	2.98	24.35	36.30	64.7	78.0
17	9	Lacerated silage	20.30	3.98	-	-	-	90.29	14.62	4.87	29.56	41.24	9.71	35.75	55.5	74.3	69.6	70.5	77.7	73.9	67.09	10.18	3.43	22.97	30.48	59.4	71.3
18	9	Lacerated, inoculated silage	20.40	3.57	-	-	-	89.08	15.09	4.45	29.91	39.63	10.92	35.11	55.3	74.4	70.3	66.9	78.7	73.5	66.28	10.61	2.98	23.54	29.13	58.2	70.0
19	10	Chopped, molassed silage	14.01	3.70	0.38	Nil	0.98	90.36	11.00	4.36	34.19	40.81	9.64	42.86	53.9	72.5	63.8	73.1	78.3	69.8	65.51	7.02	3.19	26.77	28.49	57.7	69.5
20	11	Ordinary silage, inoculated	17.12	4.30	0.46	Nil	-	88.87	17.99	5.22	30.10	35.56	11.13	35.90	58.7	73.6	76.0	69.3	82.0	66.0	65.41	13.67	3.97	24.68	23.47	58.6	70.0
21	11	Ordinary silage, inoculated, uncovered	15.31	4.50	0.43	0.04	-	90.53	16.68	5.45	31.26	37.14	9.47	41.30	54.9	70.5	66.6	66.7	80.9	64.0	63.82	11.11	3.64	25.29	23.77	56.7	68.3
22	12	Ordinary farm silage	13.47	4.20	0.33	0.08	-	92.89	9.88	2.38	35.08	45.56	7.11	42.50	52.9	65.8	59.2	68.2	70.1	63.8	61.1	5.8	1.6	24.6	29.1	47.1	63.1

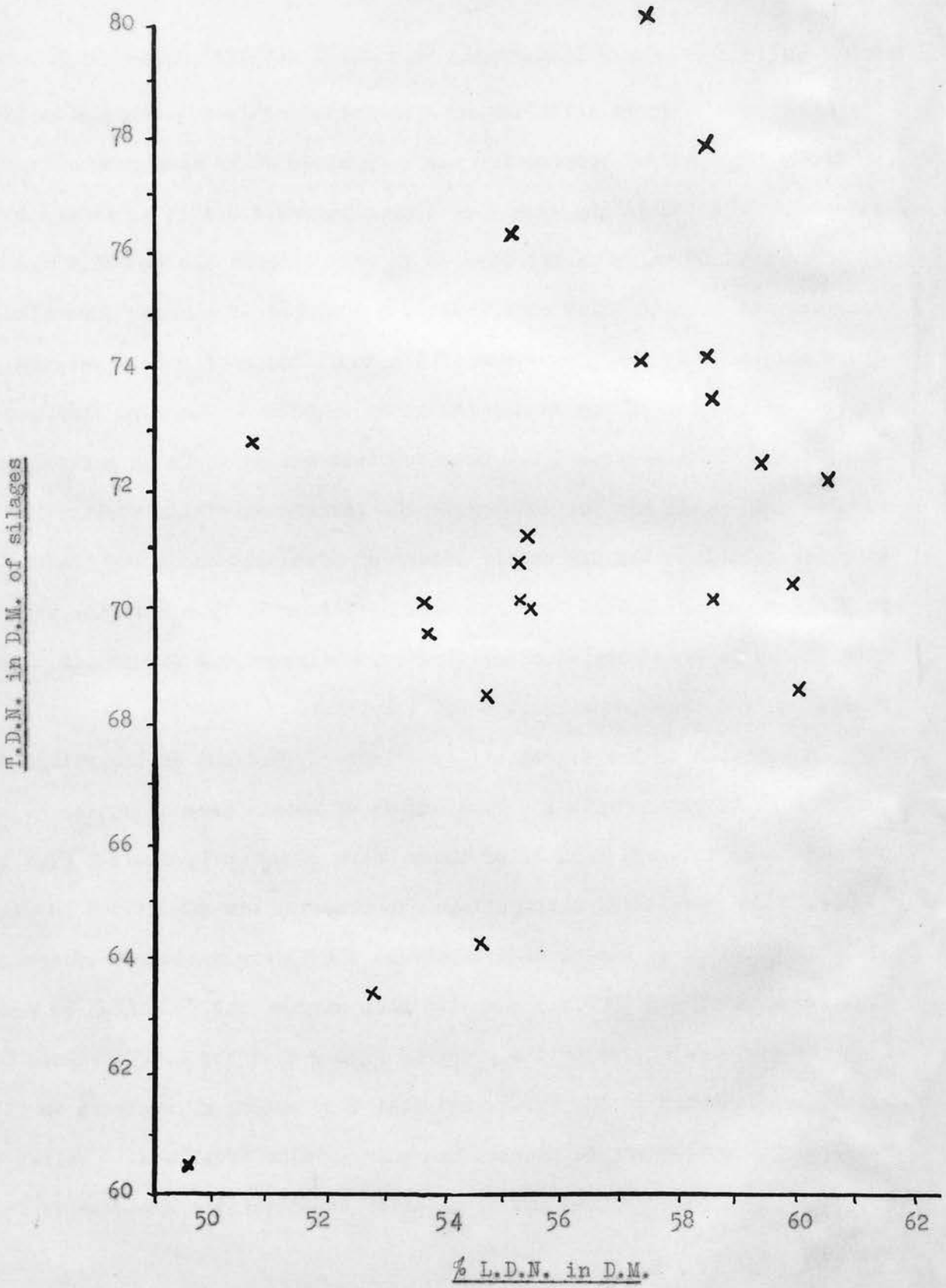
N.B. With exception of samples 1, 2 and 22 all silages were obtained from Boghall experimental silos.

(vi) Relationship between digestibility and chemical composition.

The importance of establishing some relationship between digestibility of foods and chemical composition has been stressed by many workers. One advantage of establishing such a relationship would enable an assessment of the nutritive value of the food to be made without the necessity of carrying out digestibility experiments. A number of workers have also drawn attention to the importance of the application of such a relationship to the calculation of dry matter intake by animals. The work that has been carried out in this respect has been confined mainly to fresh pasture grass studies and no one has yet considered the importance of its application in order to calculate the dry matter intake of livestock where the 'self feeding' of silage method is practised. It is with this ultimate view in mind that a general consideration in this section of the digestibility data resulting from this investigation has been made.

In addition to the digestibility trials carried out on the silage referred to in experiments 1 - 7, a number of trials were conducted on miscellaneous silages, details of these being given in Appendix 2 (Tables 79-86). The results of these silage experiments are summarized in Table 41. In addition to the usual estimations the determination of laboratory digestible nutrients (L.D.N.) has also been carried out. It can be seen from a visual inspection of the graph in Fig. 9 that the L.D.N. values bear little relationship to the T.D.N. and that this method of analysis is valueless in attempting to predict the energy value of silage. Walker and Hepburn (1956) have carried out a number of digestibility experiments on silage/

Graph showing relationship between L.D.N. content of silages and T.D.N. Fig. 9.



Graph showing relationship between C.P. content of silages and S.E. Fig. 10.

Graph showing relationship between C.F. content of silages and S.E. Fig. 11.

silage with sheep and have stated that crude fibre and cellulose are not related in any fixed way to gross digestible energy.

Attempts have been made to correlate directly S.E. values of foods with certain chemical constituents. Dijkstra (1949) has formulated regression equations for the calculation of S.E. values in silages in which he makes use of the crude protein (y), ash (n) and pH (p) values viz.:-

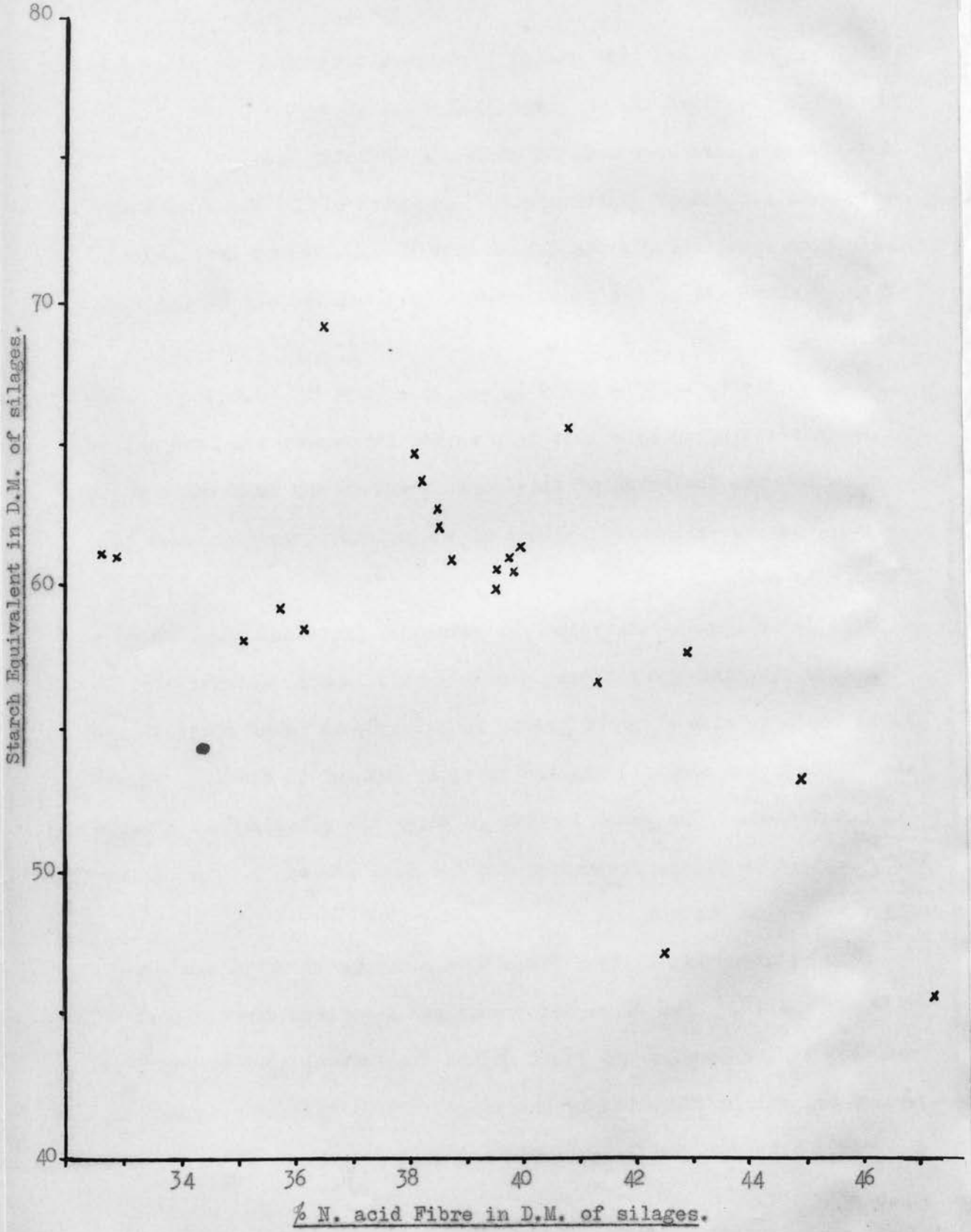
$$S.E. = -0.569\,(y - 27) - 4.159\,(p - 4.4) + (m - 12)\,(0.0473\,p - 0.966) + 51.37$$

It is interesting to note that this worker introduces ash into the equation. The inclusion of this constituent in any regression equation however, can be criticised because of the possible contamination of herbage by soil.

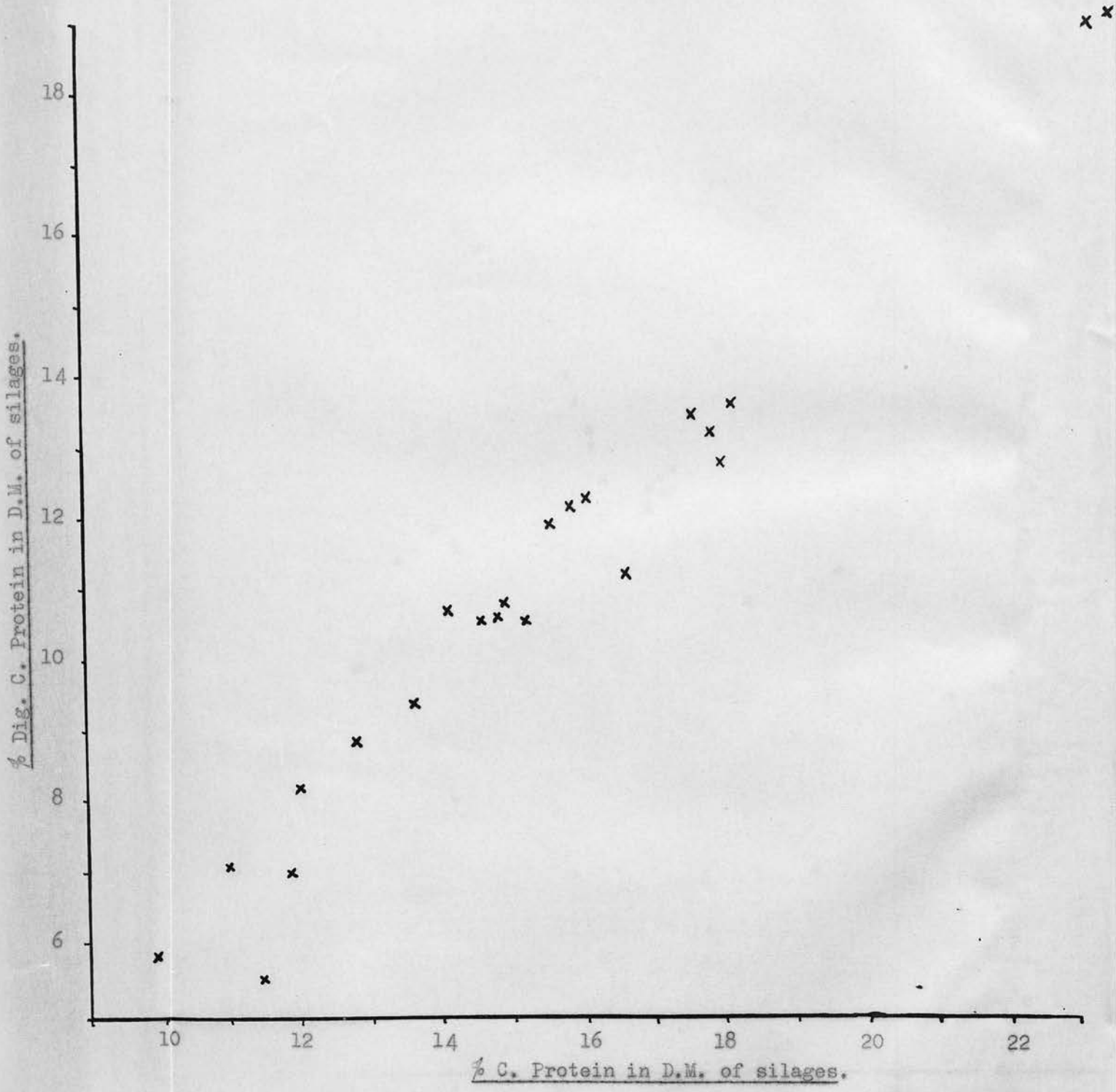
It is well known that the S.E. values of grassland crops decrease with maturity, and since there is also a relationship between protein and fibre contents with stage of growth in herbage, it is of some interest to see if these two constituents are directly related to the S.E. values in the silages studied. The graph in Fig. 10 shows the relationship between the C.P. content in silage dry matter and the S.E. value; it can be seen that there is a wide scatter.

The relationship between fibre with S.E. is shown in the graph in Figs. 11 and 12. Two fibre determinations have been carried out. In addition to the usual crude fibre method the 'normal acid fibre' (N.A.F.) method originally suggested by Hallsworth (1950) and modified by Raymond, Walker and Griffith (1955) has been used. It can be seen from these/

Graph showing relationship between N.A.F. content in silages and S.E. Fig. 12.



Graph showing relationship between C.P. in silage dry matter and D.C.P. Fig. 13.



these graphs that there is a tendency for the S.E. value to decrease as the C.F. and N.A.F. values increase, although there is a considerable scatter of the points.

Some workers have attempted to correlate organic matter digestibility with some chemical component in the feed or faeces, but the argument that organic matter is complex, composed of a vast number of chemical components each of which can vary in degree of digestibility with advancing maturity favours the consideration of a single component only when calculating digestibility relationships.

Watson (1939) has demonstrated that there is a very good correlation between D.C.P. of silage and their C.P. content. The regression equation being D.C.P. = 0.8179 C.P. - 2.4154. That this correlation holds good for silage in these studies can be seen from the graph in Fig. 13. The regression equation for the 22 silages studied being:-

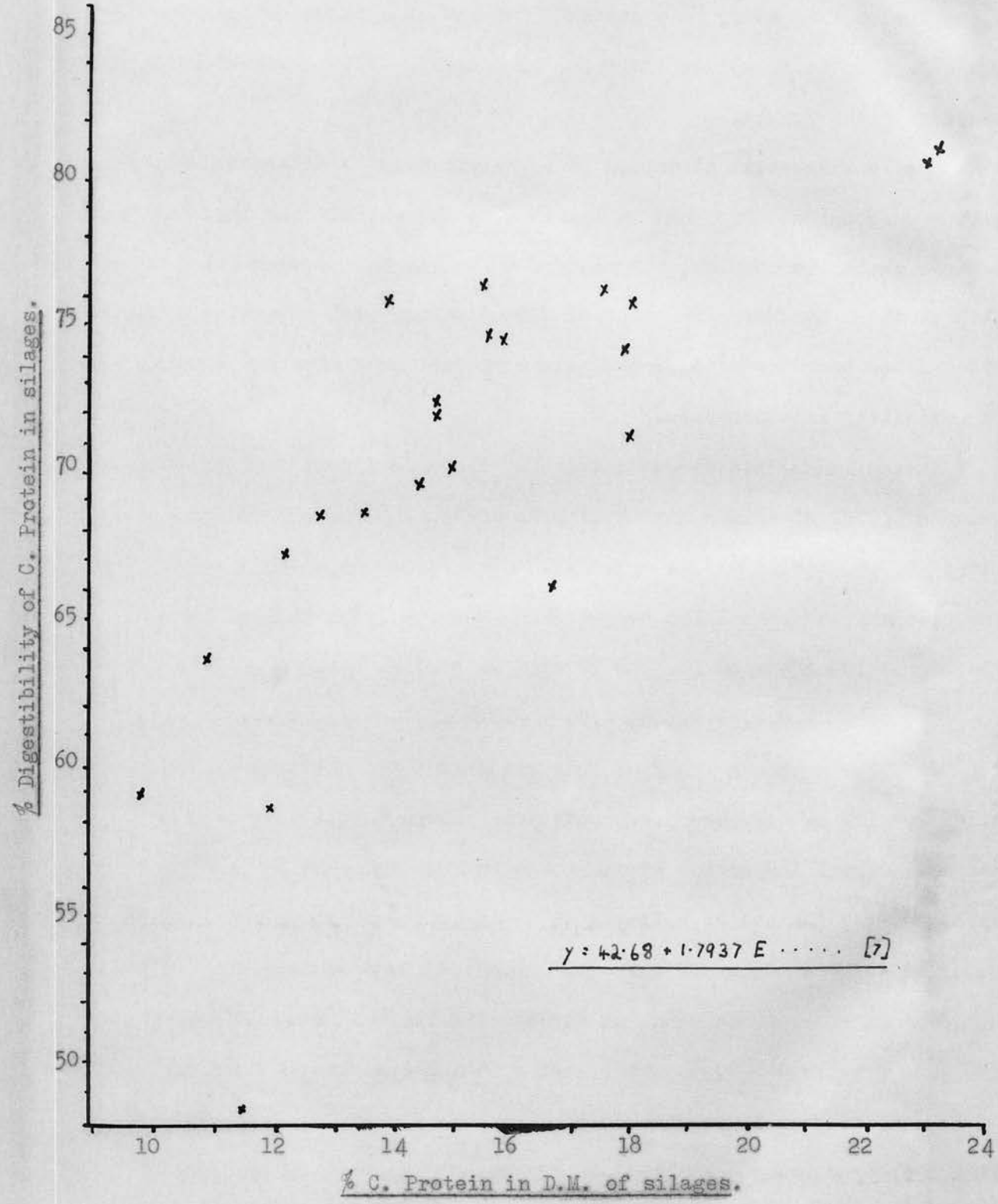
$$\text{D.C.P.} = 0.9855\ \text{C.P.} - 4.146 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [17]$$

It follows from a study of this graph that the relationships between digestibility of C.P. and C.P. content of silage should also be a good one. A visual inspection of the graph in Fig. 14 tends to confirm this hypothesis. The use of nitrogen as an indicator of digestibility has been referred to by a number of workers. Raymond (1948) showed a relationship between the nitrogen contents of herbage and the resulting faeces viz. per cent N in feed = 0.795 x per cent N in ash-free faeces + 0.14.

Lancaster (1949) has developed a method of calculating the feed intake of grazing animals based on the assumption that the weight of

nitrogen/

Graph showing relationship between C.P. content in silages and dig. of C.P. Fig. 14.



nitrogen excreted in the faeces per 100 g dry matter ingested is a constant (C). From a knowledge of the total weight of faeces voided over a given period it is a simple matter using this assumption, to calculate the herbage intake of the animal, and thence the percentage digestibility of the herbage dry matter.

Lancaster has shown that for grazing sheep the nitrogen excreted in relation to the dry matter consumed does, in fact, vary within fairly narrow limits. From the results of fifty-two trials the average value for C was 0.72 (or 4.5 when expressed in terms of crude protein) and when C was recalculated on an organic matter basis, in order to avoid errors introduced as a result of contamination of pasture with soil or dust, the value obtained was 0.83 ± 0.102. Lancaster has since suggested that these values were somewhat high since the calculated value from the results of one hundred and fifty-three trials was found to be 0.76 ± 0.113g. N per 100 g. organic matter consumed.

This finding of Lancaster's is an important one and it is of some interest to determine whether a similar constant can be applied to the nitrogen in the faeces from sheep on a silage diet. The results of the 22 digestibility experiments in Table 41, have been used for calculating the dry matter intakes by Lancaster's method and by making use of the regression equation for protein digestibility.

Lancaster's equation can be expressed simply as:-

$$A = \frac{B}{4.5} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2]$$

where A = Dry matter intake, and B = Weight of C.P. in faeces.

In/

In order to see if Lancaster's constant of 4.5 can be applied to animals on a silage diet the weight of crude protein excreted per 100 g dry matter consumed for each of the 22 trials have been calculated. It can be seen from the results in Table 42 that the value for C on a dry matter basis was 0.702 ± 0.091 (or 4.39 expressed in terms of C.P.) which agrees closely with Lancaster's original figure for pasture grass. It follows that the method of Lancaster can be applied in calculating feed intake during self feeding of silage when the C.P. content of the silages is within the range 9 - 24 per cent of the D.M.

The relationship between dry matter intake and C.P. digestibility is

$$A = D \times \frac{100}{E} \quad \text{..... [3]}$$

where D = weight of C.P. in food ingested, E = per cent C.P. in food. It follows therefore that

$$A = B \times \frac{100}{100-y} \times \frac{100}{E} \quad \text{..... [4]}$$

where y = the digestibility coefficient of C.P.

If the regression equation for calculating digestibility from C.P. content [1] be substituted for y, then the relationship becomes

$$A = B \times \frac{100}{100 - (42.68 + 1.7937\ E)} \times \frac{100}{E} \quad \text{..... [5]}$$

which simplified is:

$$A = \frac{5575\ B}{31.96E - E^2} \quad \text{..... [6]}$$

Lancaster's/

TABLE 42

B = Weight of C.P. (g) in faeces per 100 g. dry matter ingested.

E = Per cent C.P. in dry matter of silages.

Y = Digestibility coefficient of C.P. determined experimentally.

M = Calculated dry matter intake using equation [6] when actual dry matter intake is 100.

X = Digestibility coefficient calculated from regression equation [7]

L = Calculated dry matter intake using Lancaster's equation [2] when actual dry matter intake is 100.

No.	E	B	Y	X	M	L
1	11.5	5.92	48.3	63.3	140.3	135.7
2	18.0	5.20	71.1	75.0	115.4	118.5
3	23.2	4.39	81.1	84.3	120.4	100.0
4	23.1	4.45	80.7	84.1	121.2	101.4
5	18.0	4.62	74.3	75.0	99.9	105.2
6	17.8	4.16	76.6	74.6	92.1	94.8
7	15.6	4.00	76.3	70.7	87.4	91.1
8	14.1	3.38	76.0	68.0	74.8	77.0
9	12.2	3.98	67.2	64.6	92.1	90.7
10	12.0	4.97	58.6	64.2	116.9	113.2
11	13.6	4.28	68.6	67.1	95.6	97.5
12	12.9	4.06	68.5	65.8	92.1	92.5
13	15.8	4.07	74.9	71.0	88.9	92.7
14	16.0	4.10	74.4	71.4	89.5	93.4
15	14.9	4.17	72.0	69.4	91.5	95.0
16	14.7	4.10	72.2	69.1	90.1	93.4
17	14.6	4.44	69.6	68.9	97.4	101.1
18	15.1	4.48	70.3	69.8	98.1	102.1
19	11.0	3.98	63.8	62.4	96.3	90.7
20	18.0	4.32	76.0	75.0	95.9	98.4
21	16.7	5.57	66.6	72.6	121.9	126.9
22	9.9	4.03	59.2	60.4	102.9	91.8
Mean		4.39				
as N		0.702				
Standard Deviation		0.091			14.99	12.89

Lancaster's equation [2] using 4.39 as C instead of 4.5 and equation [6] have both been used in order to compare dry matter intakes, the results are shown in Table 42. It can be seen that the standard deviation values from 100 for Lancaster's method is ± 12.89 whilst the corresponding value for the regression equation method is ± 14.99. These figures indicate a slight advantage in favour of Lancaster's method. The latter method has also the advantage in that a sample of the silage is not required for protein analysis.

It can be seen from the results in Table 42 that the two experiments which show greatest divergence from the true value are Nos. 1 and 21. In the first case the sample was taken from the top of an uncovered farm silo and in the second experiment from an uncovered experimental silo. Because of the probability of increased leaching of soluble and highly digestible nitrogenous compounds where silos are left uncovered, it is undesirable to apply either regression data or Lancaster's hypothesis to badly weathered silages.

GENERAL SUMMARY

1. Three different experiments in order to compare the nutritive value of 'good' and 'bad' silages made from the same material have been described. In the first experiment a comparison between top and bottom samples taken from a large farm silo showed that considerable variation in chemical composition can occur throughout the mass. In two experiments carried out using small experimental silos, silages with pH differences of 0.5 and 0.6 respectively were produced from similar grass material. There was little difference in nutritive value between the high and low pH products in either case.

2. Two experiments were carried out in order to compare wilted grass silage and ordinary grass silage. The wilted grass silages contained slightly more sugars than the ordinary materials and were of slightly higher pH. In the first experiment the digestibilities of the various constituents were similar in the wilted and non wilted silages but in the second experiment the wilted grass silage showed significantly higher digestibility values for all constituents. The dry matter losses which occurred during ensilage were of a similar order for both materials in spite of the absence of effluent from the wilted grass silo.

3. Results for the composition and digestibility of the constituents of a medium-protein grass-clover mixture and of molassed and unmolassed silages derived from it indicated that there was little difference in nutritive value and both types compared favourably with the original grass when cut in both spring and autumn.

The/

The losses occurring in the silages made from spring grass were of a very low order whilst those obtained in the silages made from autumn grass showed losses of a greater magnitude; the unmolassed material showing the highest loss. The addition of molasses to the ordinary silage at the time of feeding did not markedly affect the digestibilities of the various constituents.

The losses encountered during haymaking from the spring grass by two different methods illustrated the advantage that silage making had over haymaking in the efficiency of the conservation process. Tripoding had a distinct advantage over field curing in that a product of higher nutritive value was obtained.

4. In a comparison of the nutritive value of spring and autumn grass cut at a similar C.P. level, little difference could be detected in composition or digestibility although considerable variation occurred in the utilization of the total digestible nitrogen. The nitrogen in the spring grass was more efficiently utilized by growing sheep than that in the autumn grass.

5. An experiment designed to compare the digestibility and nitrogen utilization of dried grass when fed at two different seasons of the year to growing sheep showed that neither season nor age of the animal had much effect upon these values. The results showed there was a tendency for young lambs (aged 9 months) to digest slightly less crude fibre than adult animals although no significant difference in nitrogen utilization was detected.

6. A study of the results of 22 digestibility experiments on grass silages ranging in C.P. content from 9.9 to 23.1 have been made and two different methods/

methods of calculating the feed intake of animals on the 'self feed' system have been compared. The value of C calculated by Lancaster's method for animals consuming fresh pasture grass compared favourably with a similar value calculated for sheep on a silage diet. Equations have been derived for calculating dry matter intakes by Lancaster's method and by a method involving the use of the C.P. content of silage.

APPENDIX I

TABLE 43

Volatile losses during oven drying at 100°C in fresh silages. Experiments 1 - 7.

Experiment	Acetic acid		Butyric acid		Nitrogen			Total Volatile loss %
	% Total	% Volatile	% Total	% Volatile	% Total	% Volatile	As NH_3.%	
No. 1								
1. Top	0.39	0.350	0.01	0.01	0.282	0.019	0.023	0.383
2. Bottom	0.16	0.096	0.87	0.70	0.553	0.095	0.115	0.911
No. 2								
1. Silos 15 + 16	0.19	0.148	Nil	Nil	0.785	0.015	0.018	0.166
2. Silos 13 + 14	0.26	0.173	Nil	Nil	0.497	0.060	0.073	0.246
No. 3								
1. Silos 11 + 12	0.34	0.326	Nil	Nil	0.436	0.033	0.040	0.366
2. Silos 13 + 14	0.48	0.463	0.02	0.02	0.446	0.060	0.073	0.555
No. 4								
1. Wilted	0.17	0.162	0.069	0.069	0.597	0.038	0.046	0.277
2. Ordinary	0.59	0.586	Nil	Nil	0.397	0.041	0.050	0.636
No. 5								
1. Wilted	0.83	0.826	Nil	Nil	0.461	0.048	0.058	0.884
2. Ordinary	0.80	0.795	Nil	Nil	0.359	0.052	0.064	0.859
No. 6								
1. Ordinary	0.22	0.192	Nil	Nil	0.464	0.042	0.052	0.244
2. Molassed	0.35	0.299	Nil	Nil	0.437	0.011	0.013	0.312
No. 7								
1. Ordinary	0.58	0.55	Nil	Nil	0.445	0.058	0.071	0.621
2. Molassed	0.55	0.51	Nil	Nil	0.437	0.060	0.073	0.583

TABLE 44

Dry Weights of food fed and faeces excreted in Experiment No. I.

	Sheep	Period	Date	Food fed	Residue	Food consumed	Faeces excreted
				g	g	g	g
1. Silage from top of silo	N	1	5.3.53- 9.3.53	4,224	Nil	4,224	1,370
	N	2	10.3.53-14.3.53	4,760	Nil	4,760	1,690
	Total			8,984		8,984	3,060
	O	1	5.3.53- 9.3.53	4,197	Nil	4,197	1,400
	O	2	10.3.53-14.3.53	4,760	Nil	4,760	1,630
	Total			8,957		8,957	3,030
2. Silage from bottom of silo	P	1	5.3.53- 9.3.53	4,255	Nil	4,255	1,450
	P	2	10.3.53-14.3.53	4,488	Nil	4,488	1,815
	Total			8,743		8,743	3,265
	Q	1	5.3.53- 9.3.53	4,214	Nil	4,214	1,815
	Q	2	10.3.53-14.3.53	4,488	Nil	4,488	1,820
	Total			8,702		8,957	3,635

TABLE 45

Composition and digestibility of farm silages. Expt. No. 1.

	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash	S.E.	T.D.N.
1. Silage from top of silo	15.31	91.41	11.52	2.97	34.51	42.41	8.59		
Faeces									
Sheep N	-	87.32	17.28	2.59	23.93	43.52	12.68		
Sheep O	-	88.02	17.85	2.71	23.99	43.47	11.98		
Dig. Coefficients									
Sheep N	65.9	67.5	48.9	70.3	76.4	65.0	-		
Sheep O	66.2	67.4	47.6	69.1	76.5	65.3	-		
Mean	66.1	67.5	48.3	69.7	76.5	65.2	-		
Dig. Nutrients									
Mean	66.1	61.2	5.56	2.07	26.38	27.62	-	53.2	64.2
2. Silage from bottom of silo	19.19	89.97	18.00	3.98	35.69	32.30	10.03		
Faeces									
Sheep P	-	87.01	13.91	3.48	27.69	41.93	12.99		
Sheep Q	-	87.70	13.77	3.70	28.82	41.41	12.30		
Dig. Coefficients									
Sheep P	63.7	64.0	71.1	67.4	71.0	51.4	-		
Sheep Q	62.2	63.1	71.0	64.8	69.5	51.5	-		
Mean	63.0	63.5	71.1	66.1	70.3	51.4	-		
Dig. Nutrients									
Mean	63.0	57.13	12.80	2.63	25.10	16.60	-	45.9	60.4

TABLE 46

Dry Weights of food fed and faeces excreted in Experiment No. 2.

	Sheep	Period	Date	Food Fed	Residue	Food consumed	Faeces excreted
				g	g	g	g
1. Silage from silos 15 and 16	P	1	10.9.53-14.9.53	5,210	Nil	5,210	1,170
	P	2	15.9.53-19.9.53	5,250	Nil	5,250	1,100
	Total			10,460		10,460	2,270
	Q	1	10.9.53-14.9.53	5,210	Nil	5,210	1,165
	Q	2	15.9.53-19.9.53	5,250	Nil	5,250	1,215
	Total			10,460		10,460	2,380
2. Silage from silos 13 and 14	P	1	25.9.53-29.9.53	3,585	Nil	3,585	650
	P	2	30.9.53-4.10.53	5,264	Nil	5,264	1,720
	Total			8,849		8,849	2,370
	Q	1	25.9.53-29.9.53	3,585	Nil	3,585	860
	Q	2	30.9.53- 4.10.53	5,264	Nil	5,264	1,245
	Total			8,849		8,849	2,105

TABLE 47

Composition and digestibility of silages from Boghall experimental silos. Expt. No. 2.

	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash	S.E.	T.D.N.
1. Silage from silos 15 and 16	21.15	91.37	23.21	6.65	28.40	33.11	8.63		
Faeces									
Sheep P	-	76.47	20.30	9.21	15.49	31.47	23.53		
Sheep Q	-	77.83	19.76	9.32	15.87	32.88	22.17		
Dig. Coefficients									
Sheep P	78.3	82.0	81.2	70.3	88.3	79.6	-		
Sheep Q	77.3	80.8	80.9	68.4	87.4	77.6	-		
Mean	77.8	81.4	81.1	69.4	87.9	78.6	-		
Dig. Nutrients									
Mean	77.8	74.38	18.82	4.62	24.96	26.02	-	69.2	80.2
2. Silage from silos 13 and 14	13.46	89.46	23.06	5.55	28.95	31.90	10.54		
Faeces									
Sheep P	-	72.59	18.60	7.90	14.80	31.29	27.41		
Sheep Q	-	72.66	18.03	7.76	14.30	32.57	27.34		
Dig. Coefficients									
Sheep P	73.2	79.1	79.2	63.3	86.8	74.7	-		
Sheep Q	76.2	81.4	82.1	68.0	88.7	76.6	-		
Mean	74.7	80.3	80.7	65.7	87.8	75.7	-		
Dig. Nutrients									
Mean	74.7	71.84	18.61	3.65	25.42	24.15	-	65.7	76.5

TABLE 48

Dry Weights of food fed and faeces excreted in Experiment No. 3.

	Sheep	Period	Date	Food fed	Residue	Food Consumed	Faeces excreted
				g	g	g	g
1. Silage from silos 11 and 12	R	1	30.4.54-4.5.54	4,143.8	Nil	4,143.8	1,133.5
	R	2	5.5.54-9.5.54	2,970.2	Nil	3,970.2	1,025.0
	Total			8,114.0		8,114.0	2,158.5
	S	1	30.4.54-4.5.54	4,140.6	Nil	4,140.6	983.5
	S	2	5.5.54-9.5.54	3,966.7	260.3	3,706.4	968.0
	Total			8,107.3		7,847.0	1,951.5
2. Silage from silos 13 and 14	T	1	30.4.54-4.5.54	4,044.3	Nil	4,044.3	949.0
	T	2	5.5.54-9.5.54	3,899.1	337	3,562.1	828.5
	Total			7,943.4		7,606.4	1,777.5
	U	1	30.4.54-4.5.54	4,044.3	Nil	4,044.3	966.5
	U	2	5.5.54-9.5.54	3,899.1	Nil	3,899.1	925.5
	Total			7,943.4		7,943.4	1,892.0

TABLE 49

Composition and digestibility of silages from Boghall experimental silos. Expt. No. 3.

	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash	S.E.	T.D.N.
1. Silage from silos 11 and 12	15.17	85.67	17.96	2.60	21.33	43.78	14.33		
Faeces									
Sheep R	-	72.50	17.95	5.44	13.94	35.17	27.50		
Sheep S	-	71.49	17.99	6.37	12.14	34.99	28.51		
Dig. Coefficients									
Sheep R	72.7	77.5	73.4	44.6	82.6	78.6	-		
Sheep S	74.5	79.3	75.1	39.2	85.8	80.1	-		
Mean	73.6	78.4	74.3	41.9	84.2	79.4	-		
Dig. Nutrients									
Mean	73.6	67.17	13.34	1.09	17.96	34.76	-	61.1	68.5
2. Silage from silos 13 and 14	15.71	85.97	17.76	2.30	22.80	43.11	14.89		
Faeces									
Sheep T	-	71.68	17.59	5.52	12.85	35.72	28.32		
Sheep U	-	71.80	17.63	4.64	14.31	35.22	28.20		
Dig. Coefficients									
Sheep T	75.8	80.5	76.8	44.0	86.9	80.6	-		
Sheep U	75.3	80.1	76.3	51.9	85.0	80.6	-		
Mean	75.6	80.3	76.6	48.0	86.0	80.6	-		
Dig. Nutrients									
Mean	75.6	69.03	13.60	1.10	19.61	34.75	-	62.6	70.4

TABLE 50

Losses during ensilage process. Expt. No. 3.

	Composition		Weight of constituents in dry matter (Kg.)			
	Grass	Silage	Grass	Silage	Weight lost (Kg.)	% Loss
1. Inoculated silage (silos 11 and 12)						
Dry matter	17.26	15.17	62.89	55.06	7.83	12.45
Organic matter	87.84	85.67	55.25	47.17	8.08	14.62
Crude protein	16.23	17.96	10.21	9.89	0.32	3.13
Ether extract	3.86	2.60	2.43	1.43	1.00	41.15
Crude fibre	21.86	21.33	13.75	11.74	2.01	14.62
N-free-extractives	45.89	43.78	28.86	24.11	4.75	16.46
2. Control silage (silos 13 and 14)						
Dry matter	17.26	15.71	63.66	57.02	6.64	10.43
Organic matter	87.84	85.97	55.92	49.02	6.10	10.91
Crude protein	16.23	17.76	10.33	10.13	0.20	1.94
Ether extract	3.86	2.30	2.46	1.31	1.15	46.74
Crude fibre	21.86	22.80	13.92	13.00	0.92	6.61
N-free-extractives	45.89	43.11	29.21	24.58	4.63	15.85

TABLE 51

Constituents lost in effluents Expt. No. 3

	Date	Volume ml.	Dry matter g./100 ml.	Dry matter total wt. g.	Nitrogen g./100 ml.	Nitrogen total wt. g.	Ash g./100 ml.	Ash total wt. g.
1. Silo No. 11	11.10.53	50	0.137	0.069	0.0003	0.00015	0.1086	0.0543
	3.11.53	246	0.081	0.199	0.0002	0.0049	0.052	0.1279
	21.4.54	3,500	7.240	253.40	0.3300	11.550	2.030	71.050
	Total	3,796		253.668		11.5506		71.232
2. Silo No. 12	11.10.53	100	0.054	0.054	Nil	Nil	0.0284	0.0284
	3.11.53	254	0.194	0.493	0.0056	0.0142	0.118	0.2997
	21. 4.54	3,220	6,940	223.468	0.320	10.304	1.900	61.180
	Total	3,574		224.015		10.3182		61.5081
3. Silo No. 13	11.10.53	1,970	0.2192	4.318	0.0007	0.0138	0.1155	2.2754
	3.11.53	336	1.828	6.142	0.0616	0.2070	0.700	2.3520
	21. 4.54	890	6.55	58.295	0.330	2.9370	1.95	17.3550
	Total	3,196		68.755		3.1578		21.9824
4. Silo No. 14	11.10.53	3,000	0.3283	9.849	0.0008	0.0240	0.1542	4.6260
	20.10.53	170	1.0790	1.834	0.0026	0.0044	0.4267	0.7254
	3.11.53	400	2.9510	11.804	0.0910	0.3640	0.9960	3.9840
	21. 4.54	2,580	7.2500	187.050	0.3000	7.7400	2.1000	54.1800
	Total	6,150		210.537		8.1324		63.5154

TABLE 52

Dry weights of food feed and faeces excreted in Experiment No. 4

	Sheep	Period	Date	Food fed	Residue	Food consumed	Faeces excreted
				g	g	g	g
1, Wilted silage	N	1	16.3.54-20.3.54	7,876.0	Nil	7,876.0	1,913
	N	2	21.3.54-25.3.54	7,738.0	Nil	7,738.0	1,988
		Total		15,614.0		15,614.0	3,901
	O	1	16.3.54-20.3.54	7,876.0	Nil	7,876.0	1,834
	O	2	21.3.54-25.3.54	7,738.0	Nil	7,738.0	1,883
		Total		15,614.0		15,614.0	3,717
2. Ordinary silage	P	1	16.3.54-20.3.54	7,441.9	Nil	7,441.9	1,858.5
	P	2	21.3.54-25.3.54	8,181.1	Nil	8,181.1	1,962.0
		Total		15,623.0		15,623.0	3,820.5
	Q	1	16.3.54-20.3.54	7,441.9	Nil	7,441.9	1,905.5
	Q	2	21.3.54-25.3.54	8,181.1	Nil	8,181.1	1,938.0
		Total		15,623.0		15,623.0	3,843.5

TABLE 53.

Dry Weights of foods fed and faeces excreted in Experiment No. 4.

Fresh grass + hay experiments

	Sheep	Period	Date	Food Fed	Residue	Food Consumed	Faeces Excreted
				g	g	g	g
3. Fresh grass	P	1	3.6.53- 7.6.53	5,886	Nil	5,886	1,710
	P	2	8.6.53-12.6.53	6,141	Nil	6,141	1,534
	Total			12,027		12,027	3,244
	Q	1	3.6.53- 7.6.53	5,886	Nil	5,886	1,360
	Q	2	8,6.53- 7.6.53	6,141	Nil	6,141	1,463
	Total			12,027		12,027	2,823
4. Hay	N	1	5.8.53-8. 8. 53	4,536	Nil	4,536	1,461
	N	2	9.8.53-12.8.53	4,564	Nil	4,564	1,596
	Total			9,100		9,100	3,057
	O	1	5.8.53- 8.8.53	4,536	Nil	4,536	1,579
	O	2	9.8.53-12.8.53	4,564	Nil	4,564	1,611
	Total			9,100		9,100	3,190

TABLE 54

% Composition and digestibility of grass fed to sheep. Expt. No. 4.

	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash	S.E.	T.D.N.
Grass									
Sample 1	20.0	87.79	12.98	2.15	25.22	47.44	12.21		
2	18.9	88.98	12.83	2.66	25.65	47.84	11.02		
3	18.7	91.05	13.98	2.50	24.49	50.08	8.95		
4	20.5	92.03	13.44	2.85	23.96	51.78	7.97		
5	20.0	91.77	14.95	2.85	24.64	49.33	8.23		
6	21.5	92.69	12.66	2.50	22.97	54.56	7.31		
7	20.2	92.59	12.90	2.91	23.72	53.06	7.41		
8	16.5	92.78	13.34	2.83	25.74	50.87	7.22		
9	20.9	93.59	12.55	2.99	25.42	52.63	6.41		
10	20.5	92.79	10.49	2.24	24.14	55.92	7.21		
Mean	19.8	91.60	13.01	2.65	24.58	51.36	8.40		
Faeces									
Sheep P		83.02	15.82	3.39	22.74	41.07	16.99		
Sheep Q		82.80	16.29	3.83	22.91	39.77	17.20		
Dig. Coefficients									
Sheep P	73.0	75.6	67.2	65.5	75.0	78.4	-		
Sheep Q	76.5	78.8	70.6	66.1	78.1	81.8	-		
Mean	74.8	77.2	68.9	65.8	76.6	80.1	-		
Dig. Nutrients									
Mean	74.8	70.72	8.96	1.74	18.83	41.14	-	63.8	72.9

TABLE 55

% Composition and digestibility of hay fed to sheep. Expt. No. 4.

	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash	S.E.	T.D.N.
Hay	86.95	90.26	14.43	1.99	32.01	41.83	9.74		
Faeces									
Sheep N	-	86.49	15.05	3.45	23.24	44.74	13.52		
Sheep O	-	85.87	16.10	3.75	22.03	43.99	14.13		
Dig. Coefficients									
Sheep N	66.4	67.8	65.0	41.7	75.6	64.1	-		
Sheep O	65.0	66.8	60.9	33.7	75.9	63.1	-		
Mean	65.7	67.3	63.0	37.7	75.8	63.5	-		
Dig. Nutrients									
Mean	65.7	60.74	9.09	0.75	24.26	25.56	-	42.2	61.6

TABLE 56

% Composition and digestibility of wilted grass silage and fresh grass silage. Expt. No. 4.

	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash	S.E.	T.D.N.
1. Wilted grass silage	23.98	90.77	15.57	3.67	27.37	44.16	9.23		
Faeces									
Sheep N	-	83.94	14.74	4.05	23.10	42.05	16.06		
Sheep O	-	83.49	15.55	4.67	23.00	40.27	16.51		
Dig. Coefficients									
Sheep N	74.7	76.9	76.4	72.4	78.9	76.2	-		
Sheep O	75.9	78.1	76.2	69.6	80.0	78.3	-		
Mean	75.3	77.5	76.3	71.0	79.5	77.3	-		
Dig. Nutrients									
Mean	75.3	70.34	11.88	2.61	21.76	34.14	-	62.7	73.6
2. Fresh grass silage	17.65	90.90	14.07	2.54	28.31	45.98	9.10		
Faeces									
Sheep P	-	81.32	13.73	3.60	23.47	40.52	18.68		
Sheep Q	-	81.56	13.76	4.30	22.42	41.08	18.44		
Dig. Coefficients									
Sheep P	75.6	78.1	76.1	65.2	79.7	78.5	-		
Sheep Q	75.4	77.9	75.9	58.4	80.5	78.0	-		
Mean	75.5	78.0	76.0	61.8	80.1	78.3	-		
Dig. Nutrients									
Mean	75.5	70.90	10.69	1.57	22.68	36.00	-	62.1	72.9

TABLE 57

Losses during ensilage process. Expt. No. 4.

	% Composition		Weights of constituents in dry matter			
	Grass	Silage	Grass (Kg.)	Silage (Kg.)	Weight of Constituent lost (Kg.)	% Loss
1. Wilted grass silage.						
Dry matter	26.90	23.98	168.17	145.01	23.16	13.77
Organic matter	91.94	90.77	154.62	131.63	22.99	14.87
Crude protein	12.60	15.57	21.19	22.58	+ 1.39	+ 6.56
Ether extract	2.25	3.67	3.78	5.32	+ 1.54	+40.74
Crude fibre	28.80	27.37	48.43	36.69	8.74	18.05
N.F.E.	48.29	44.16	81.21	64.04	17.17	21.14
2. Fresh grass silage.						
Dry matter	18.50	17.65	131.70	113.15	18.55	14.09
Organic matter	91.55	90.90	120.57	102.85	17.72	14.70
Crude protein	12.88	14.07	16.96	15.92	1.04	6.13
Ether extract	1.92	2.54	2.53	2.87	+ 0.34	+13.44
Crude fibre	27.69	28.31	36.47	32.03	4.44	12.17
N.F.E.	49.06	45.98	64.61	52.03	12.58	25.64

TABLE 58

Constituents lost in effluents Expt. No. 4.

	Date	Volume ml.	Dry matter g./100 ml.	Dry matter total wt. g.	Nitrogen g./100 ml.	Nitrogen total wt. g.
1. Fresh grass silage	8.6.53	2,000	2.62	52.40	0.074	1.48
	17.6.53	22,594	6.91	1,561.25	0.238	53.77
	22.6.53	4,000	6.91	276.40	0.238	9.52
	30.6.53	5,819	7.16	416.64	0.249	14.49
	4.3.54	12,774	6.87	877.57	0.198	25.29
	5.3.54	864	6.09	52.62	0.198	1.71
	8.3.54	2,137	6.09	130.14	0.198	4.23
	Totals	50,188		3,367.02		110.49
2. Wilted grass silage	No effluent produced.					

TABLE 59

Dry Weights of food fed and faeces excreted in Experiment No. 5.

	Sheep	Period	Date	Food fed	Residue	Food consumed	Faeces excreted
				g	g	g	g
1. Wilted silage	T	1	21.1.55-25.1.55	4,814.3	Nil	4814.3	1,084.1
	T	2	26.1.55-30.1.55	4,675.5	Nil	4,675.5	1,233.5
	Total			9,489.8		9,489.8	2,317.6
	U	1	21.1.55-25.1.55	4,814.3	Nil	4,814.8	985.0
	U	2	26.1.55-30.1.55	4,675.5	Nil	4,675.5	1,164.0
	Total			9,489.8		9,489.8	2,149.0
2. Ordinary silage	R	1	21.1.55-25.1.55	4,111.3	Nil	4,111.3	1,070.3
	R	2	26.1.55-30.1.55	4,685.7	1,189	3,496.7	1,115.6
	Total			8,797.0		7,608.0	2,185.9
	S	1	21.1.55-25.1.55	4,111.3	Nil	4,111.3	1,111.0
	S	2	26.1.55-30.1.55	4,685.7	1,388.0	3,297.7	1,114.0
	Total			8,797.0		7,409.0	2,225.0

TABLE 60

% Composition and digestibility of wilted grass silage and fresh grass silage. Expt. No. 5.

	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash	S.E.	T.D.N.
1. Wilted grass silage	23.71	88.26	12.15	3.23	29.31	43.57	11.74		
Faeces									
Sheep T	-	74.08	17.54	3.57	16.64	36.33	25.92		
Sheep U	-	73.68	16.26	2.45	15.65	39.32	26.32		
Dig. Coefficients									
Sheep T	77.3	80.9	67.2	74.9	87.1	81.0	-		
Sheep U	75.5	79.6	67.2	81.4	86.9	77.9	-		
Mean	76.4	80.3	67.2	78.2	87.0	79.5			
Dig. Nutrients									
Mean	76.4	70.87	8.16	2.53	25.50	34.64	-	62.6	74.0
2. Fresh grass silage	18.72	88.09	11.99	3.44	29.93	42.73	11.91		
Faeces									
Sheep R	-	74.32	15.89	2.94	19.17	36.32	25.68		
Sheep S	-	72.08	17.72	3.01	16.24	35.11	27.92		
Dig. Coefficients									
Sheep R	71.1	75.7	61.8	75.3	81.5	75.5	-		
Sheep S	67.1	75.3	55.3	73.6	83.6	75.2	-		
Mean	69.1	75.5	58.6	74.5	82.6	75.4	-		
Dig. Nutrients									
Mean	69.1	66.51	7.03	2.56	24.72	32.22	-	58.2	69.7

TABLE 61

Losses during ensilage process. Expt. No. 5.

	% Composition					
	Grass	Silage	Grass (Kg.)	Silage (Kg.)	Wt. of constituent lost (Kg.)	% Loss
1. Wilted grass silage						
Dry matter	24.40	23.71	174.92	154.90	20.02	11.45
Organic matter	90.87	88.26	158.95	136.71	22.24	13.99
Crude protein	11.87	12.15	20.76	18.82	1.94	9.35
Ether extract	2.00	3.23	3.50	5.00	+ 1.50	+ 42.86
Crude fibre	28.13	29.31	49.20	45.40	3.80	7.72
N.F.E.	48.87	43.57	85.48	67.49	17.99	21.05
2. Fresh grass silage						
Dry matter	18.20	18.72	129.97	115.24	14.73	11.33
Organic matter	90.50	88.09	117.62	101.55	16.07	13.66
Crude protein	11.87	11.99	15.43	13.82	1.61	10.43
Ether extract	2.00	3.44	2.60	3.96	+ 1.36	+ 52.31
Crude fibre	28.60	29.93	37.17	34.49	2.68	7.21
N.F.E.	48.03	42.73	62.42	49.24	13.18	21.12

TABLE 62

Constituents lost in effluents Expt. No. 5.

	Date	Volume ml.	Dry matter g./100 ml.	Dry matter total wt. g.	Nitrogen g./100 ml.	Nitrogen total wt. g.
1. Fresh grass silage	5.6.54	4,546	6.06	275.49	0.13	5.91
	11.6.54	10,501	7.01	736.12	0.19	19.95
	17.6.54	7,365	6.53	480.93	0.21	15.47
	24.6.54	5,819	6.63	385.81	0.23	13.38
	2.7.54	6,273	7.19	451.03	0.25	15.68
	9.7.54	3,546	6.89	244.32	0.23	8.16
	16.7.54	2,819	7.34	206.91	0.25	7.05
	13.1.55	6,819	6.96	474.60	0.27	18.41
	Totals	47,688		3,255.21		104.01
2. Wilted grass silage	No effluents produced.					

TABLE 63

Dry Weights of food fed and faeces excreted in Experiment No. 6.

	Sheep	Period	Date	Food fed g	Residue g	Food consumed g	Faeces excreted g
1. Control silage	T	1	25.8.54-28.8.54	5,098.5	Nil	5,098.5	1,352.7
	T	2	29.8.54- 1.9.54	4,952.5	Nil	4,952.5	1,293.5
	Total			10,051.0		10,051.0	2,646.2
	U	1	25.8.54-28.8.54	5,098.5	252	4,846.5	1,268.2
	U	2	29.8.54- 1.9.54	4,952.5	Nil	4,952.5	1,247.9
	Total			10,051.0		9,751.5	2,516.1
2. *Control silage + molasses	R	1	25.8.54-28.8.54	5,098.5	117	4,981.5	1,492.4
	R	2	29.8.54- 1.9.54	4,952.5	Nil	4,952.5	1,384.2
	Total			10,051.0		9,934.0	2,876.6
	S	1	25.8.54-28.8.54	5,098.5	Nil	5,098.5	1,457.4
	S	2	29.8.54- 1.9.54	4,952.5	Nil	4,952.5	1,385.8
	Total			10,051.0		10,051.0	2,843.2
	* Food fed figures exclude weight of molasses (92.7 g/day) fed.						
3. Molassed silage	R	1	11.9.54-15.9.54	6,283.7	Nil	6,283.7	1,637.5
	R	2	16.9.54-20.9.54	6,265.3	Nil	6,265.3	1,681.2
	Total			12,549.0		12,549.0	3,318.7
	S	1	11.9.54-15.9.54	6,283.7	Nil	6,283.7	1,442.0
	S	2	16.9.54-20.9.54	6,265.3	Nil	6,265.3	1,660.3
	Total			12,549.0		12,549.0	3,102.3

TABLE 64

Dry Weights of foods fed and faeces excreted in Experiment No. 6.

Fresh grass + hay experiments

	Sheep	Period	Date	Food fed g	Residue g	Food consumed g	Faeces excreted g
4. Fresh grass	S	1	28.5.54- 1.6.54	4,381	Nil	4,381	1,138.0
	S	2	2.6.54-6.6.54	5,221	211	5,010	1,356.5
	Total			9,602		9,391	2,494.5
	T	1	28.5.54- 1.6.54	4,381	Nil	4,381	1,058.5
	T	2	2.6.54- 6.6.54	5,221	123	5,098	1,300.0
	Total			9,602		9,479	2,358.5
5. Tripod Hay	T	1	23.11.54-27.11.54	5,880	Nil	5,880	1,953.6
	T	2	28.11.54- 2,12.54	5,850	Nil	5,850	1,963.3
	Total			11,730		11,730	3.916.9
	U	1	23.11.54-27.11.54	5,880	Nil	5,880	2,008.5
	U	2	28.11.54- 2.12.54	5,850	Nil	5,850	2,035.6
	Total			11,730		11,730	4,044.1
6. Field cured Hay	R	1	23.11.54-27.11.54	5,865	Nil	5,865	2,458.7
	R	2	28.11.54- 2.12.54	5,775	785	4,990	2,192.9
	Total			11,640		10,855	4,651.6
	S	1	23.11.54-27.11.54	5,865	Nil	5,865	2,300.7
	S	2	28.11.54- 2.12.54	5,775	Nil	5,775	2,648.8
	Total			11,640		11,640	4,949.5

TABLE 65

% Composition and digestibility of spring grass fed to sheep. Expt. No. 6.

	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash	S.E.	T.D.N.
Grass									
Sample 1	15.70	91.70	12.49	2.47	25.67	51.07	8.30		
2	15.56	91.86	12.47	2.30	25.72	51.37	8.14		
3	18.56	92.43	11.56	2.28	26.75	51.84	7.57		
4	18.40	92.73	11.68	2.28	26.99	51.78	7.27		
5	19.40	92.84	10.82	2.38	26.45	53.19	7.16		
6	17.70	92.87	11.92	2.03	26.57	52.35	7.13		
7	21.42	93.24	10.32	2.19	26.79	53.94	6.76		
8	21.25	93.51	10.66	2.15	26.67	54.03	6.49		
9	22.15	93.34	9.98	1.75	28.43	53.18	6.66		
10	21.90	93.64	9.24	2.11	28.03	54.26	6.36		
Mean	19.20	92.82	11.11	2.20	26.81	52.70	7.18		
Faeces									
Sheep S	-	85.91	15.90	4.56	23.96	41.49	14.09		
Sheep T	-	85.59	15.20	5.05	24.57	40.77	14.41		
Dig. Coefficients									
Sheep S	73.5	75.4	61.6	44.5	76.3	79.1	-		
Sheep T	75.1	77.1	65.6	42.4	77.3	80.6	-		
Mean	74.3	76.3	63.6	43.5	76.8	79.9	-		
Dig. Nutrients									

TABLE 66

% Composition and digestibility of hays fed to sheep. Expt. No. 6.

	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash	S.E.	T.D.N.
1. Field cured hay.	77.6	92.50	9.89	1.40	36.19	45.02	7.50		
Faeces									
Sheep R	-	88.86	12.17	2.87	26.01	47.81	11.14		
Sheep S	-	88.50	12.29	2.98	25.90	47.33	11.50		
Dig. Coefficients									
Sheep R	57.2	58.8	47.3	12.2	69.2	54.5	-		
Sheep S	57.5	59.3	47.2	9.5	69.6	55.3	-		
Mean	57.4	59.1	47.3	10.9	69.4	54.9			
Dig. Nutrients									
Mean	57.4	54.67	4.67	0.15	25.12	26.56	-	35.4	56.7
2. Tripod hay	78.2	90.78	12.11	1.58	32.41	44.68	9.22		
Faeces									
Sheep T	-	86.66	14.31	3.43	22.66	46.26	13.34		
Sheep U	-	86.95	14.74	3.29	23.37	45.55	13.05		
Dig. Coefficients									
Sheep T	66.6	68.1	60.5	27.5	76.7	65.4	-		
Sheep U	65.5	67.0	58.0	28.2	75.1	64.9	-		
Mean	66.1	67.6	59.3	27.9	75.9	65.2	-		
Dig. Nutrients									
Mean	66.1	61.37	7.18	0.44	24.60	29.13	-	42.5	61.9

TABLE 67

% Composition and digestibility of silages. Expt. No. 6.

	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash	S.E.	T.D.N.
1. Control silage	21.30	91.44	13.63	3.15	30.45	44.21	8.56		
Faeces									
Sheep T	-	82.64	16.26	4.87	22.66	38.85	17.36		
Sheep U	-	83.43	16.69	4.70	21.75	40.29	16.57		
Dig. Coefficients									
Sheep T	74.4	76.2	68.6	59.3	80.4	76.9	-		
Sheep U	73.7	76.6	68.6	61.7	81.7	76.6	-		
Mean	74.1	76.4	68.6	60.5	81.1	76.8	-		
Dig. Nutrients									
Mean	74.1	69.86	9.35	1.91	24.69	33.96	-	60.7	72.3
2. Control silage + molasses*	21.30	91.38	13.24	3.00	29.09	46.05	8.62		
Faeces									
Sheep R	-	84.60	16.07	4.02	24.49	40.02	15.40		
Sheep S	-	83.36	16.51	4.37	22.16	40.32	16.64		
Dig. Coefficients									
Sheep R	73.9	74.7	66.7	63.0	76.7	76.5	-		
Sheep S	73.4	77.7	66.5	60.8	79.4	76.9	-		

TABLE 67

% Composition and digestibility of silages. Expt. No. 6 (Continued)

	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash	S.E.	T.D.N.
3. Molassed silage	21.20	91.29	12.88	3.30	30.35	44.76	8.71		
Faeces									
Sheep R	-	84.39	16.00	5.44	23.55	39.40	15.61		
Sheep S	-	83.77	15.78	5.68	23.41	38.90	16.23		
Dig. Coefficients									
Sheep R	73.5	75.6	67.2	56.4	79.5	76.7	-		
Sheep S	75.3	77.3	69.7	57.5	80.7	78.5	-		
Mean	74.4	76.5	68.5	57.0	80.1	77.6	-		
Dig. Nutrients									
Mean	74.4	69.82	8.82	1.88	24.31	34.74	-	60.6	72.1

* D.M. figure excludes molasses added.

TABLE 68

Constituents lost in effluents Expt. No.6.

	Date	Volume ml.	Dry matter g./100 ml.	Dry matter total wt. g.	Nitrogen g./100 ml.	Nitrogen total wt. g.	Ash g./100 ml.	Ash total wt. g.
1. Control silage.			No effluent produced.					
2. Molassed silage.	4.6.54	3,460	17.83	616.92	0.182	6.30	2.25	77.85
	11.6.54	570	21.20	120.84	0.210	1.20	2.85	16.25
	16.8.54	2,130	13.02	277.33	0.176	3.75	2.46	52.40
	Totals			1,015.09		11.25		146.50

TABLE 69

Total and digestible losses during haymaking. Expt. No. 6.

	Total wts. constituents							
	Grass Kg.	Hay Kg.	Wt. of const. lost Kg.	% Loss	Grass Kg.	Hay Kg.	Wt. of dig. nut. lost Kg.	% Loss
1. Field cured hay								
Dry matter	95.16	54.39	40.77	42.84	70.69	31.22	39.47	55.84
Organic matter	88.71	50.31	38.40	43.29	62.80	29.73	33.07	52.66
Crude protein	12.17	5.38	6.79	55.79	7.74	2.54	5.20	67.18
Ether extract	2.09	0.76	1.33	63.64	0.91	0.08	0.83	91.21
Crude fibre	25.55	19.69	5.86	22.94	19.62	13.66	5.96	30.38
N.F.E.	48.88	24.48	14.40	29.46	39.05	14.45	24.60	62.99
S.E.	-	-	-	-	59.28	19.25	40.03	67.53
T.D.N.	-	-	-	-	68.52	30.84	37.68	54.99
2. Tripod Hay								
Dry matter	95.16	56.57	38.59	40.55	70.69	37.39	33.30	47.12
Organic matter	88.71	51.35	37.36	42.11	62.80	34.72	28.08	44.71
Crude protein	12.17	6.85	5.32	43.71	7.74	4.06	3.68	47.55
Ether extract	2.09	0.89	1.20	57.42	0.91	0.25	0.66	72.53
Crude fibre	25.55	18.33	7.22	28.26	19.62	13.92	5.70	29.05
N.F.E.	48.88	25.27	23.61	48.30	39.05	16.46	22.59	57.85
S.E.	-	-	-	-	59.28	24.04	35.24	59.45
T.D.N.	-	-	-	-	68.52	35.02	33.50	51.11

TABLE 70

Total Losses during ensilage processes

	% Composition		Weights of constituents in dry matter ensiled		Weight of constituents lost (Kg.)	% Loss
	Grass	Silage	Grass (Kg.)	Silage (Kg.)		
1. Control silage						
Dry matter	21.3	21.3	149.86	148.22	1.64	1.11
Organic matter	93.21	91.44	139.68	135.53	4.15	1.09
Crude protein	12.79	13.63	19.19	20.19	+1.00	+ 5.21
Ether extract	2.20	3.15	3.30	4.67	+1.37	+41.51
Crude fibre	26.85	30.45	40.24	45.13	+4.89	+12.15
N.F.E.	51.37	44.21	76.95	65.54	11.46	14.83
Soluble sugars	5.45	4.23	8.16	6.26	1.90	23.29
Fructosan	2.68	0.47	4.01	0.70	3.31	82.55
N.H_2SO_4 ext.	11.41	11.13	17.10	16.50	0.60	3.51
72% H_2SO_4 ext.	24.26	22.54	36.36	33.41	2.95	8.11
Org. residue	10.87	10.84	16.29	16.11	0.18	1.10
2. Molassed silage						
Dry matter	21.6	21.2	139.59	135.55	4.04	2.89
Organic matter	93.06	91.28	129.90	123.72	6.18	4.76
Crude protein	12.50	12.88	17.50	17.44	0.06	0.36
Ether extract	2.17	3.30	3.03	4.47	+1.44	+47.52
Crude fibre	25.73	30.35	36.01	41.15	+5.14	+14.27
N.F.E.	52.66	44.76	73.36	60.70	12.66	17.26
Soluble sugars	7.96	4.15	11.15	5.63	5.52	49.51
Fructosan	2.55	3.68	3.59	4.99	+1.40	+38.99
N.H_2SO_4 ext	10.97	11.61	15.31	15.74	+0.43	+ 2.81
72% H_2SO_4 ext.	23.30	22.36	32.53	30.31	2.22	6.82
Org. residue	10.44	10.69	14.58	14.49	0.09	0.62

TABLE 72

Dry Weights of food fed and faeces excreted in Experiment No. 7

	Sheep	Period	Date	Food fed g	Residue g	Food consumed g	Faeces excreted g
1. Control silage	T	1	2.5.55- 6.5.55	5,209.9	Nil	5,209.9	1,264
	T	2	7.5.55-11.5.55	4,611.8	Nil	4,611.8	1,259
	Total			9,821.7		9,821.7	2,523
	U	1	2.5.55- 6.5.55	5,209.9	Nil	5,209.9	1,517
	U	2	7.5.55-11.5.55	4,611.8	Nil	4,611.8	1,637
	Total			9,821.7		9,821.7	3,154
2. *Control silage + molasses	R	1	9.5.55-13.5.55	5,274.2	Nil	5,274.2	1,811
	R	2	14.5.55-18.5.55	5,904.6	Nil	5,904.6	1,713
	Total			11,178.8		11,178.8	3,524
	S	1	9.5.55- 6.5.55	5,274.2	Nil	5,274.2	1,787
	S	2	7.5.55-11.5.55	5,904.6	Nil	5,904.6	1,759
	Total			11,178.8		11,178.8	3,546
	*Food fed figures exclude weight of molasses (180.88g/day)added.						
3. Molassed silage	T	1	3.4.55- 7.4.55	4,901.6	Nil	4,901.6	1,446.0
	T	2	8.4.55-12.4.55	4,754.7	Nil	4,754.7	1,324.5
	Total			9,656.3		9,656.3	2,770.5
	U	1	3.4.55- 7.4.55	4,394.9	Nil	4,394.9	1,280
	U	2	8.4.55 -12.4.55	5,343.4	Nil	5,343.4	1,440
	Total			9,738.3		9,738.3	2,720
4. Fresh grass	T	1	6.9.54-10.9.54	4,280	Nil	4,280	1,205
	T	2	11.9.54-15.9.54	4,335	Nil	4,335	1,264
	Total			8,615		8,615	2,469
	U	1	6.9.54-10.9.54	4,280	Nil	4,280	1,234
	U	2	11.9.54-15.9.54	4,335	Nil	4,335	1,215
	Total			8,615		8,615	2,449

TABLE 73

% Composition and digestibility of autumn grass. Expt. No. 7.

	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash	S.E.	T.D.N.
Grass									
Sample 1	16.6	90.31	13.93	4.29	26.32	45.77	9.69		
2	18.6	88.21	12.82	4.13	25.97	45.29	11.79		
3	17.7	89.21	13.25	4.14	27.55	44.27	10.79		
4	17.5	90.34	12.20	4.15	28.07	45.92	9.66		
5	15.0	90.89	11.82	3.80	28.46	46.85	9.11		
6	16.8	90.06	13.47	3.97	27.51	45.11	9.94		
7	16.3	89.45	12.93	3.96	27.12	45.44	10.55		
8	16.7	89.33	12.81	3.94	26.32	46.26	10.67		
9	18.9	89.75	12.33	3.78	26.65	46.17	10.25		
10	18.0	89.51	12.10	3.72	27.47	46.22	10.49		
Mean	17.2	89.71	12.77	3.99	27.14	45.81	10.29		
Faeces									
Sheep T	-	80.17	14.65	4.65	26.33	34.54	19.83		
Sheep U	-	79.81	14.11	5.19	24.90	35.61	20.19		
Dig. Coefficients									
Sheep T	71.4	74.4	67.1	66.6	72.2	78.3	-		
Sheep U	71.6	74.7	68.6	63.0	73.9	77.9	-		
Mean	71.5	74.6	67.9	64.8	73.1	78.1	-		
Dig. Nutrients									
Mean	71.5	66.8	8.7	2.6	19.8	35.8	-	60.8	70.0

TABLE 74.

% Composition and digestibility of silages. Expt. No. 7

	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash	S.E.	T.D.N.
1. Control silage	17.57	88.95	15.81	4.50	26.26	42.38	11.05		
Faeces									
Sheep T	-	77.74	13.56	6.44	18.92	38.82	22.26		
Sheep U	-	78.31	13.92	6.07	19.65	38.67	21.69		
Dig. Coefficients									
Sheep T	74.3	77.6	78.0	63.2	81.5	76.5			
Sheep U	67.9	71.7	71.7	56.7	76.0	70.7			
Mean	71.1	74.7	74.9	60.0	78.8	73.6			
Dig. Nutrients									
Mean	71.1	66.44	11.84	2.70	20.69	31.19	-	61.0	69.8
2. Control silage + molasses	19.10	89.59	13.75	3.83	22.38	59.63	10.41		
Faeces									
Sheep R	-	81.67	15.82	5.63	19.61	18.33	40.61		
Sheep S	-	80.78	16.22	5.57	19.48	19.22	39.51		
Dig. Coefficients									
Sheep R	72.9	75.3	68.8	60.1	76.4	81.5			
Sheep S	72.8	75.4	67.8	60.3	76.2	81.9			
Mean	72.9	75.4	68.3	60.2	76.3	81.7			

TABLE 74

% Composition and digestibility of silages. Expt. No. 7 (Condintued)

	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N.F.E.	Ash	S.E.	T.D.N.
3. Molassed silage	17.10	89.04	15.97	4.68	24.47	40.92	10.96		
Faeces									
Sheep T	-	77.63	14.28	5.95	18.16	39.24	22.37		
Sheep U	-	78.39	14.63	5.91	19.03	38.82	21.61		
Dig. Coefficients									
Sheep T	71.3	75.0	74.4	63.5	81.0	72.5			
Sheep U	72.1	75.4	74.4	64.7	80.7	73.5			
Mean	71.7	75.2	74.4	64.1	80.9	73.0			
Dig. Nutrients									
Mean	71.7	66.96	11.88	3.00	22.22	29.87	-	61.0	70.7

TABLE 75

Total losses during ensilage process. Expt. No. 7.

	% Composition		Weights of constituents in dry matter ensiled			
	Grass	Silage	Grass (Kg.)	Silage (Kg.)	Weight of Constituents lost (Kg.)	% Loss
1. Ordinary silage						
Dry matter	15.89	17.57	97.63	81.90	15.73	16.11
Organic matter	90.94	88.95	88.78	72.85		
Crude protein	15.25	15.81	15.13	12.95	2.19	14.46
Ether extract	3.81	4.50	3.72	3.69	0.03	0.81
Crude fibre	26.95	26.26	26.31	21.51	4.80	18.24
N.F.E.	44.93	42.38	43.87	34.71	9.16	20.87
Soluble sugars	2.02	0.45	1.97	0.37	1.60	81.22
Fructosan	10.60	0.38	10.35	0.31	10.04	97.00
N.H_2SO_4 ext.	11.89	12.22	11.49	10.01	1.48	12.88
72% H_2SO_4 ext.	28.28	24.72	27.61	20.25	7.36	26.66
Org. residue	11.67	13.17	11.28	10.79	0.49	4.34
2. Molassed silage						
Dry matter	15.89	17.10	72.84	65.57	7.27	9.98
Organic matter	90.88	89.04	66.20	58.38	7.82	11.81
Crude protein	14.73	15.97	10.73	10.50	0.23	3.47
Ether extract	3.61	4.68	2.63	3.07	- 0.44	- 1.67
Crude fibre	25.49	27.47	18.57	18.01	0.56	3.02
N.F.E.	47.05	40.92	34.27	26.80	7.47	21.80
Soluble sugars	4.81	0.94	3.50	0.62	2.88	82.29
Fructosan	10.03	0.51	7.31	0.33	6.97	95.33
N.H_2SO_4 ext.	11.25	12.42	8.19	8.14	0.05	0.61
72% H_2SO_4 ext.	26.75	24.85	19.48	16.29	3.19	16.38
Org. residue	11.04	12.82	8.04	8.41	- 0.37	- 4.60

TABLE 76

Digestible losses during ensilage process. Expt. No. 7.

	% Dig. Nutrients		Wt. of dig. nutrients in dry matter		Wt. of dig. nutrients lost	% Loss
	Grass	Silage	Grass (Kg.)	Silage (Kg.)	(Kg.)	
1. Ordinary silage						
Dry matter	71.5	71.1	69.81	58.23	11.58	16.59
Organic matter	67.84	66.44	66.23	54.41	11.82	17.85
Crude protein	10.35	11.84	10.10	9.70	0.40	3.96
Ether extract	2.47	2.70	2.41	2.21	0.20	8.30
Crude fibre	19.70	20.69	19.23	16.95	2.28	11.86
N.F.E.	35.09	31.19	34.26	25.54	8.72	25.45
2. *Molassed silage						
Dry matter	71.5	71.7	52.08	47.01	5.07	9.74
Organic matter	67.84	66.96	49.41	43.91	5.50	11.13
Crude protein	10.35	11.88	7.54	7.79	- 0.25	- 3.32
Ether extract	2.47	3.00	1.80	1.97	- 0.17	- 9.44
Crude fibre	19.70	22.22	14.35	14.57	- 0.22	- 1.53
N.F.E	35.09	29.87	25.56	19.59	5.97	23.36

* Excluding molasses added.

TABLE 77

Constituents lost in effluents. Expt. No. 7.

	Date	Volume	Dry matter g./100 ml.	Dry matter total wt.	Ash g./100 ml.	Ash total wt.	Nitrogen g./100 ml.	Nitrogen total wt.	Total sugars mg./100 ml.	Total sugars total wt.
		litres		g		g		g		g
1. Control Silage	13.9.54	8.80	2.97	261.36	1.00	88.00	0.11	9.68	7.29	0.64
	16.9.54	17.61	3.71	653.33	1.32	232.45	0.16	28.18	8.02	1.41
	21.9.54	5.11	4.28	218.71	1.45	74.10	0.19	9.71	18.26	0.93
	1.10.54	5.68	3.91	222.09	1.03	58.50	0.20	11.36	4.14	0.24
	7.1.55	16.05	4.32	693.36	1.74	279.27	0.23	36.92	44.70	7.17
	10.3.55	24.28	4.83	1,172.72	1.61	390.91	0.23	55.84	76.28	18.52
	28.3.55	3.12	5.72	178.46	1.93	60.22	0.24	7.49	63.83	1.99
	Totals	80.65		3,400.03		1,083.45		159.18		30.90
2. Molassed Silage	13.9.54	12.78	3.98	508.64	1.06	135.47	1.01	129.08	2.81	0.36
	16.9.54	12.50	3.07	392.35	1.02	130.36	0.10	12.78	7.36	0.94
	21.9.54	3.40	3.91	132.94	1.42	48.28	0.15	5.10	45.41	1.54
	1.10.54	23.00	4.04	929.20	1.05	241.50	0.16	36.80	Nil	Nil
	7.1.55	13.92	3.48	484.42	1.50	208.80	0.21	29.23	0.07	0.01
	10.3.55	21.02	6.81	1,431.46	1.63	342.63	0.22	46.24	88.48	18.60
	28.3.55	3.83	6.02	230.57	2.00	76.60	0127	10.34	64.84	2.48
	Totals	90.45		4,109.58		1,183.64		269.57		23.93

TABLE 78

Dry Weights of food fed and faeces excreted in Experiment No. 8.

	Sheep	Period	Date	Food fed g	Residue g	Food consumed g	Faeces excreted g
July	A	1	4.7.55- 8.7.55	5,975	Nil	5,975	2,936.8
		2	9.7.55-13.7.55	5,975	Nil	5,975	2,872.2
		Total		11,950		11,950	5,809.0
	B	1					3,027.7
		2	"	"	"	"	2,724.4
		Total					5,752.1
	T	1	"	6,967.5	Nil	6,967.5	3,355.0
		2		6,967.5	Nil	6,967.5	3,247.7
		Total		13,935.0		13,935.0	6,602.7
	U	19	"	7,965.5	Nil	7,965.5	3,830.5
		2		7,965.5	Nil	7,965.5	3,703.0
		Total		15,931.0		15,931.0	7,533.5
November	A	1	14.11.55-18.11.55	6,985	Nil	6,985	3,293.0
		2	19.11.55-23.11.55	6,985	Nil	6,985	3,299.7
		Total		13,970		13,970	6,592.7
	B	1	"	7,045	Nil	7,045	3,286.4
		2		7,045	Nil	7,045	3,402.7
		Total		14,090		14,090	6,689.1
	T	1	"	9,680	Nil	9,680	5,037.1
		2		9,680	Nil	9,680	4,634.4
		Total		19,760		19,760	9,671.5
	U	1	"	8,750	Nil	8,750	4,161.4
		2		8,750	Nil	8,750	4,260.3
		Total		17,500		17,500	8,421.7
	F	1	"	5,430	Nil	5,430	2,636.0
		2		5,430	Nil	5,430	2,835.5
		Total		10,860		10,860	5,471.5
	G	1	"	"	"	"	2,671.4
		2					2,819.0
		Total					5,490.4

APPENDIX II

TABLE 79

SILAGE EXPERIMENT No. 9. Ref. No. 15.

Original material: grass-clover (1st Year ley).

Treatment:- long herbage - no additive.

Date of ensiling:- 13th May, 1952. Date silo opened:- 4th August, 1952.

Silo:- Boghall exp. large silo No. 6.

Duration of experiment:- 11th August, 1952 - 25th August, 1952 (15 days).

Number of sheep used:- Two

	Food consumed during trial (D.M.) (g)	Faeces excreted (D.M.) (g)
Sheep N	12,232	3,037
Sheep P	8,792	2,403

Composition and Digestibility

	Composition			Digestibility			
	Silage	Faeces		Dig. Coef.			Dig.Nutrients
	%	N	P	N	P	Mean	Mean
Dry matter	18.95	-	-	75.1	72.7	73.9	73.9
pH	3.99	-	-	-			-
Acetic acid	-	-	-	-			-
Butyric acid		-	-	-			-
Lactic acid		-	-	-			-
Organic matter	90.05	80.27	78.04	78.5	76.1	77.3	69.61
Crude protein	14.89	16.13	15.82	72.8	71.2	72.0	10.72
Ether extract	5.17	6.09	4.64	71.3	74.7	73.0	3.77
Crude Fibre	28.73	22.72	21.15	80.5	79.6	80.0	22.98
N.F.E.	41.27	35.33	36.43	79.4	75.6	77.5	31.98
Ash	9.95	19.73	21.96	-	-	-	-
Starch Equ.							63.8
T.D.N.							74.1
N.A.F.	38.16						
L.D.N.	58.4						

TABLE 80

SILAGE EXPERIMENT No. 9. Ref. No. 16.

Original material: grass-clover (1st year ley) Similar material as in Expt. No. 1.

Treatment:- long herbage; inoculated with Lactobacillus culture.

Date of ensiling:- 13th May, 1952. Date Silo opened:- 5th August, 1952.

Silo:- Boghall exp. large silo No. 5.

Duration of experiment:- 11th August, 1952 - 25th August, 1952 (15 days).

Number of sheep used:- Two.

	Food consumed during trial (D.M.) (g)	Faeces excreted (D.M.) (g)
Sheep O	9,492	2,089
Sheep Q	9,984	2,568

Composition and Digestibility

	Composition			Digestibility			
	Silage	Faeces %		Dig.			Dig. Nutrients
	%	O	Q	O	Q	Mean	Mean
Dry matter	19.60	-	-	78.0	74.2	76.1	76.1
pH	3.63	-	-	-			-
Acetic acid		-	-	-			-
Butyric acid		-	-	-			-
Lactic acid		-	-	-			-
Organic matter	89.89	77.50	79.25	80.8	77.3	79.0	71.01
Crude protein	14.74	17.12	17.23	74.7	69.6	72.2	10.64
Ether extract	4.38	6.36	5.42	68.0	68.1	68.0	2.98
Crude fibre	29.20	19.31	21.29	85.3	81.4	83.4	24.35
N.F.E.	41.57	34.71	35.31	81.7	78.0	80.9	36.30
Ash	10.11	22.50	20.75	-	-	-	-
Starch Equ.							64.7
T.D.N.							78.0
N.A.F.	38.16						
L.D.N.	58.4						

TABLE 81

SILAGE EXPERIMENT No. 9. Ref. No. 17

Original material: grass-clover (1st Year ley). Similar material as in Exp. No. 1.

Treatment:- lacerated herbage, no additive.

Date of ensiling:- 13th May, 1956. Date silo opened:- 6th August, 1952.

Silo:- Boghall exp. silo No. 2.

Duration of experiment:- 11th August, 1952 - 25th August, 1952 (15 days).

Number of sheep used:- Two.

	Food consumed during trial (D.M.) (g)	Faeces excreted (D.M.) (g)
Sheep P	10,129	2,819
Sheep N	13,575	4,077

Composition and Digestiblity

	Composition			Digestiblity			
	Silage	Faeces %		Dig.		Dig. Nutrients	
	%	P	N	P	N	Mean	Mean
Dry matter	20.30	-	-	72.2	70.0	71.1	71.1
pH	3.98	-	-		-		-
Acetic acid		-	-		-		-
Butryic acid		-	-		-		-
Lactic acid		-	-		-		-
Organic matter	90.29	80.05	80.93	75.4	73.1	74.3	67.09
Crude protein	14.62	15.30	15.53	70.6	68.5	69.6	10.18
Ether extract	4.87	5.28	4.68	69.1	71.9	70.5	3.43
Crude fibre	29.56	22.69	23.01	78.4	76.9	77.7	22.97
N.F.E.	41.24	36.78	37.71	75.6	72.1	73.9	30.48
Ash	9.71	19.95	19.07	-	-	-	-
Starch Equ.							59.4
T.D.N.							71.3
N.A.F.	35.75						
L.D.N.	55.5						

TABLE 82

SILAGE EXPERIMENT No. 9. Ref. No. 18.

Original material: grass-clover (1st year ley). Similar material as in Expt. No. 1.

Treatment:- lacerated herbage, inoculated with Lactobacillus spp. culture.

Date of ensiling:- 13th May, 1952 Date silo opened:- 6th August, 1952.

Silo:- Boghall exp. large silo No. I.

Duration of experiment:- 11th August, 1952 - 25th August, 1952 (15 days).

Number of sheep used:- Two.

	Food consumed during trial (D.M.) (g)	Faeces excreted (D.M.) (g)
Sheep Q	11,243	3,415
Sheep O	10,700	2,953

Composition and Digestibility

	Composition			Digestibility			
	Silage	Faeces %		Dig.			Dig. Nutrients
	%	Q	O	Q	O	Mean	Mean
Dry matter	20.40	-		69.6	72.3	71.0	71.0
pH	3.57	-			-		
Acetic acid		-			-		
Butyric acid		-			-		
Lactic acid		-			-		
Organic matter	89.08	79.66	77.73	72.8	75.9	74.4	66.28
Crude protein	15.09	15.61	15.25	68.6	72.0	70.3	10.61
Ether extract	4.45	4.76	5.43	67.2	66.6	66.9	2.98
Crude fibre	29.91	22.93	20.88	76.8	80.6	78.7	23.54
N. free ext.	39.63	36.36	36.17	72.1	74.8	73.5	29.13
Starch Equ.							58.2
T.D.N.							70.0
N.A.F.	35.11						
L.D.N.	55.3						

TABLE 83

SILAGE EXPERIMENT No. 10. Ref. No. 19.

Original material: grass-clover

Treatment:- Chopped and molassed (Rate - 1 gal. molasses/ton fresh herbage).

Date of ensiling:- 20th May, 1952 Date silo opened:- 6th October, 1952.

Silo:- Boghall exp. small silo No. 12.

Duration of experiment:- 8th October, 1952 - 22nd October, 1952 (15 days)

Number of sheep used:- Two.

	Food consumed during trial (D.M.) (g)	Faeces excreted (D.M.) (g)
Sheep N	8,733	2,869
Sheep O	8,733	2,675

Composition and Digestibility

	Composition			Digestibility			
	Silage	Faeces %		Dig.			Dig. Nutrients
	%	N	O	N	O	Mean	Mean
Dry matter	14.01	-	-	67.3	69.4	68.4	68.4
pH	3.70	-	-	-			-
Acetic acid	0.38	-	-	-			-
Butyric acid	Nil	-	-	-			-
Lactic acid	0.98	-	-	-			-
Organic matter	90.36	78.47	78.61	71.5	73.4	72.5	65.51
Crude protein	11.00	12.06	13.04	63.9	63.7	63.8	7.02
Ether extract	4.36	3.61	3.80	72.7	73.5	73.1	3.19
Crude fibre	34.19	23.97	22.82	77.0	79.6	78.3	26.77
N. free ext.	40.81	38.80	38.96	68.8	70.8	69.8	28.49
Ash	9.64	21.53	21.39	-	-	-	-
Starch Equ.							57.7
T.D.N.							69.5
N.A.F.	42.86						
L.D.N.	53.9						

TABLE 84

SILAGE EXPERIMENT No. 11. Ref. No. 20.

Original material: Grass and clover.

Treatment:- Long herbage, inoculated with lactobacilli spp., covered silo.

Date of ensiling:- 25th August, 1952. Date silo opened:- 12th December, 1952.

Silo:- Boghall exp. small silo No. 11.

Duration of experiment:- 16th December, 1952 - 28th December, 1952 (13 days).

Number of sheep used:- Two.

	Food consumed during trial (D.M.) (g)	Faeces excreted (D.M.) (g)
Sheep N	7,705	2,265
Sheep O	7,705	2,185

Composition and Digestibility

	Composition			Digestibility			
	Silage	Faeces %		Dig.			Dig. Nutrients
	%	N	O	N	O	Mean	Mean
Dry matter	17.12	-		70.6	71.6	71.2	71.2
pH	4.3	-			-		
Acetic acid	0.46	-			-		
Butyric acid	Nil	-			-		
Lactic acid	-	-			-		
Organic matter	88.87	81.22	81.77	73.1	74.0	73.6	65.41
Crude protein	17.99	14.44	15.51	76.4	75.5	76.0	13.67
Ether extract	5.22	5.15	5.96	71.0	67.6	69.3	3.97
Crude fibre	30.10	19.65	18.70	80.8	83.2	82.0	24.68
N. free ext.	35.56	41.98	41.60	65.3	66.8	66.0	23.47
Ash	11.13	18.78	18.23	-	-	-	-
Starch Equ.							58.6
T.D.N.							70.0
N.A.F.	35.90						
L.D.N.	58.7						

TABLE 85

SILAGE EXPERIMENT No. 11. Ref. No. 21

Original material: Grass and clover (Similar material as in Exp. No. 7).

Treatment:- long herbage, inoculated with Lactobacilli. Uncovered silo.

Date of ensiling:- 25th August, 1952. Date silo opened:- 16th December, 1952.

Silo:- Boghall exp. small silo No. 15.

Duration of experiment:- 2nd January, 1953 - 14th January, 1953 (13 days).

Number of sheep used:- Two.

	Food consumed during trial (D.M.) (g)	Faeces excreted (D.M.) (g)
Sheep N	6,890	2,255
Sheep O	6,890	2,200

Composition and Digestibility

	Composition			Digestibility			
	Silage	Faeces %		Dig.		Dig. Nutrients	
	%	N	O	N	O	Mean	Mean
Dry matter	15.31	-	-	67 .1	67.8	67.5	67.5
pH	4.5	-	-		-		-
Acetic acid	0.43	-	-		-		-
Butyric acid	0.04	-	-		-		-
Lactic acid	-	-	-		-		-
Organic matter	90.53	83.21	82.31	69.9	71.0	70.5	63.82
Crude protein	16.68	17.82	16.65	65.0	68.1	66.6	11.11
Ether extract	5.45	5.58	5.69	66.5	66.8	66.7	3.64
Crude fibre	31.26	18.74	18.21	80.4	81.4	80.9	25.29
N. free ext.	37.14	41.07	41.76	63.8	64.1	64.0	23.77
Ash	9.47	16.79	17.69	-	-	-	-
Starch Equ.							56.7
T.D.N.							68.3
N.A.F.	41.30						
L.D.N.	54.9						

TABLE 86

SILAGE EXPERIMENT No. 12. Ref. No. 22.

Original material : grass and clover.

Treatments:- ordinary farm silage made from fresh herbage.

Date of ensiling:- Date silo opened:-

Silo:- Trench silo.

Duration of experiment:- 13th April, 1953 - 20th April, 1953 (8 days).

Number of sheep used:- Two.

	Food consumed during trial (D.M.) (g)	Faeces excreted (D.M.) (g)
Sheep P	9,037	3,335
Sheep Q	9,037	3,250

Composition and Digestibility

	Composition			Digestibility			
	Silage	Faeces %		Dig.		Dig. Nutrients	
	%	P	Q	P	Q	Mean	Mean
Dry matter	13.47	-	-	63.1	64.0	63.6	63.6
pH	4.2	-	-		-		-
Acetic acid	0.328	-	-		-		-
Butyric acid	0.083	-	-		-		-
Lactic acid	-	-	-		-		-
Organic matter	92.89	87.15	86.68	65.2	66.3	65.8	61.1
Crude protein	9.88	11.16	11.13	58.6	59.7	59.2	5.8
Ether extract	2.38	2.00	2.14	68.4	67.9	68.2	1.6
Crude fibre	35.08	28.81	28.18	69.3	70.8	70.1	24.6
N. free ext.	45.56	45.18	45.23	63.4	64.2	63.8	29.1
Ash	7.11	12.85	13.32	-	-	-	-
Starch Equ.							47.1
T.D.N.							63.1
N.A.F.	42.50						
L.D.N.	52.9						

APPENDIX III

ANALYTICAL METHODS

Carbohydrate Estimations

1. Somogyi estimation for reducing sugars.

Reagents:- N. Potassium Iodate, 2.5% Potassium Iodide, 2N Sulphuric acid, 0.1 N Sodium Thiosulphate.

Standard Copper Reagent:- (1 Litre contains 28 g. anhydrous disodium phosphate, 100 ml. N. sodium hydroxide, 40 g. Rochelle salt, 8 g. copper sulphate (pentahydrate) and 180 g. anhydrous sodium sulphate).

The copper reagent is prepared as follows:- The phosphate and tartrate are dissolved in about 700 ml. water, the caustic soda is added and then with stirring, 80 ml. of a 10% copper sulphate solution are introduced. Finally the sodium sulphate is added and dissolved and the solution is diluted to 1 litre and allowed to stand for a day or two, during which time impurities settle out. The clear top part of the solution is decanted, and the remainder filtered; 25 ml. of normal potassium iodate per litre of reagent are then added. This concentration is suitable for detecting up to 3 mg. sugar in 5 ml. solution.

Method:-

5 ml. of the clarified extract are pipetted into a large boiling tube followed by 5 ml. of the Somogyi reagent containing potassium iodate. The tube is stoppered and heated by immersion in a boiling water bath for 20 minutes. After cooling, 2 ml. of 2.5% potassium iodide are added, running it/

it down to the walls of the test tube, followed by 2.5 ml. of 2N sulphuric acid (this acid is added quickly from a burette with a large outlet) together with simultaneous agitation so that the entire contents are mixed and acidified at once. The excess liberated iodine is then titrated with 0.005 N. sodium thiosulphate using a 1% starch solution as indicator. Duplicate blanks containing 5 ml. water mixed with 5 ml. reagent are included with each determination.

Then ml. sodium thiosulphate equivalent to sugar = ml. for blank - ml. for back titration; and mg. sugar in 5 ml. solution = ml. thiosulphate x factor. The following factors were determined with pure sugar solutions:-

Glucose	0.136
Xylose	0.136
Fructose	0.141

2. Total sugars.

Two grams of the dried sample (or ten grams of fresh silage or grass) are placed in a Soxhlet thimble and extracted with 90% alcohol for 7 hours. The concentration of the alcohol in the extraction unit can be maintained at 90% by placing 100 ml. of 80% alcohol in the Soxhlet flask at the commencement of the estimation. When fresh silage or grass determinations are carried out, the sample in the Soxhlet thimble is washed with absolute alcohol, prior to the 90% extraction, in order to precipitate any fructosen which may have come into solution during the mincing operation. The residue after the 7 hours extraction is dried and kept for fructosan estimation. The alcohol in the Soxhlet flask is evaporated off, 20 ml. of water/

water being added when the volume is reduced to about 50 ml. This extract is clarified by the simultaneous addition of 10 ml. of 0.5 N cadmium sulphate and a similar volume of 0.5 N sodium hydroxide, maintaining the temperature of the solution at 100°C for 2 minutes. After cooling, the mixture is filtered (Whatman No. I), washed with water and made up to 200 ml. In addition to the Somogyi estimation carried out on this extract after hydrolysis with sulphuric acid (15 ml. extract + 5 ml. 2 N. sulphuric acid) for 4 hours, the total fructose units are also determined by means of the Roe method as follows:-

To a 5 ml. of a solution of 'acid reagent' (130 g. glycerol, 100 ml. conc. hydrochloric acid containing 45 mg. copper sulphate (pentahydrate) per litre, and 50 ml. of water) are added 1 ml. of a solution of resorcinol in water (0.45%) and 2 ml. of the fructose solution. After thorough mixing, the tube is stoppered and the contents are heated in a boiling water bath for exactly 12 mins., then cooled and read against a blank carried through the process simultaneously in a photoelectric absorbtiometer using a violet (601) filter.

From a knowledge of the total fructose units present in the alcohol extract a correction for fructose decomposition during the 4 hours hydrolysis, assuming 31.7% is destroyed, is made in the final calculation. The total reducing value is expressed in terms of glucose.

3./

3. Fructosan.

The residue from the alcohol extraction is shaken with cold water (100 ml.) for six hours, filtered, washed and shaken with a further 100 ml. of water for six hours. The combined extracts are diluted to 250 ml. and the fructosan determined, (as fructose), after a 10 minute hydrolysis in a solution which is 0.5 N with respect to sulphuric acid, and after neutralization with sodium hydroxide, by means of the Somogyi method.

4. Normal acid extract.

The residue from the water extract is boiled gently under reflux, with 100 ml. N. sulphuric acid for one hour. The material is filtered, (Whatman No. 54) and the volume made up to 500 ml. 11.1 ml. of this extract are made normal by the addition of 8.9 ml. 2 N sulphuric acid and this is refluxed in a boiling water bath for 4 hours in order to hydrolyse completely the carbohydrates. After cooling and neutralizing the volume is made up to 50 ml. and a Somogyi estimation carried out on a 5 ml. aliquot. The results are expressed in terms of glucose.

5. 72 per cent acid extract.

The residue from the 'normal acid extract' is treated with 15 ml. of 72% $^{w}/_{w}$ sulphuric acid at a temperature of $18^{\circ}C \pm 2^{\circ}$ for 4 hours, the mixture being stirred from time to time. The solution is made normal by the addition of 352.5 ml. water, relfuxed for 2 hours then filtered through an asbestos lined Gooch crucible. The filtrate is made up to 500 ml. An

aliquot/

aliquot (20 ml.) is taken, neutralized made up to 50 ml. and a Somogyi estimation carried out on a 5 ml. aliquot. The results are expressed in terms of glucose.

6. Insoluble organic residue.

The residue from the above extraction is dried at 100°C, weighed, ignited, loss on ignition is designated insoluble organic residue.

Normal acid fibre.

A one gram dried and milled sample is extracted for 7 hours in a Soxhlet extraction apparatus with alcohol-benzene (1 part alcohol to 2 parts benzene). The residue is then digested in a litre conical flask with 200 ml. N sulphuric acid. The acid is added hot and brought to the boil quickly and then kept gently boiling under a reflux for 1 hour. The material is then filtered through a sintered silica crucible (50 ml. capacity) of porosity I.

The residue is washed with 250 ml. of hot water and then alcohol and dried to constant weight at 100°C then ashed for half an hour at 600°C. The result is expressed on a dry matter basis.

Laboratory Digestible Nutrients

A one gram portion of the dried ground material is treated with 100 ml. of 0.5 N hydrochloric acid and autoclaved in an open Erlenmeyer flask at 15 lbs. pressure for 1 hour. The material is immediately filtered through

a/

a sintered silica crucible of porosity I and the residue washed with warm water, dried at 100°C and weighed. The original sample weight minus the weight of the dried residue converted to a percentage is referred to as Laboratory Digestible Nutrients (L.D.N.)

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PUBLISHED WORK

A joint paper has already been published by Dr. D. Purves and the author incorporating some of the results of the work described in Experiment 6 of this thesis. The reference to this is:- J. Sci. Fd. Agric. 7, 189. 1956.